RTTY FROM A to Z

DURWARD J. TUCKER W5VU

A Handbook for the Professional or Amateur

CQ TECHNICAL SERIES

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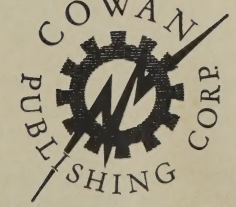
by

Durward J. Tucker
W5VU



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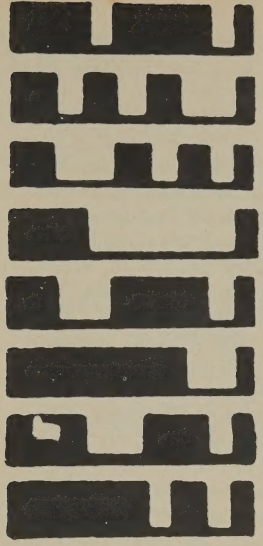

PREFACE

RTTY, to many, is a vague, if not mysterious mode of communications. Basic information on this subject is relatively scarce compared to other subjects such as telephony, s.s.b., c.w., etc. This applies especially to amateur radio, but even for commercial applications general information on the subject leaves much to be desired.

Perhaps the reason for this is that there has been no meteoric rise in RTTY communications, such as the telegraph, telephone, and radio experienced. Actually, the teleprinter has, in some form or other, been around for quite some time, over a hundred years, in fact. RTTY has grown and grown, but over a considerable span of years. World War II gave it quite a boost and its growth tempo has increased considerably the last few years due to its expanding applications.

Realizing the need for a complete and thorough treatment of the subject, the Editor and management of *CQ—The Radio Amateurs Journal,* induced Durward J. Tucker, a very capable and versatile registered Professional Engineer and radio amateur, to write a series of articles on the RTTY subject for *CQ,* which ran for a period of two years (24 articles).

The series was well received by the amateur, the commercial man and the professional man. The series was so well received and there were so many requests for the material in reprint form, that it became imperative that the material be reproduced in book form, which was pretty obvious all along. It was also pretty obvious that this would have to be done long before all of the material could be published in *CQ,* since that would take over four years, running continuously with an article every month.

Durward J. Tucker, W5VU, is a radio broadcast executive, being Managing Director of 5000 watt WRR-AM station and 100 kw WRR-FM station for the past eighteen years.

As a veteran broadcaster, he is very active in broadcasting, being on the Board of Directors of the Mutual Broadcasting System, a Director of the Texas Association of Broadcasters, and Chairman of the State Industry Advisory Committee to the FCC for Texas. Under his direction is not only the Emergency Broadcast System (which replaced Conelrad), but Police radio, Fire radio, Petroleum, Citizens Band, Public Utilities, Industrial, as well as Amateur Radio, and, in fact, all radio for the State of Texas. (Quite a chore within itself—even if you didn't have a regular job to take care of) Director of Communications for Civil Defense for Dallas and Dallas County (another healthy chore). Being an advertising man, he frequents New York and other advertising centers and is certainly no stranger to Madison Avenue. He is a 32° Mason and Shriner, and is closely associated with many Dallas civic organizations and activities, and is well known to the music lovers in Dallas since WRR-FM is one of the nation's outstanding classical music stations.

Durward is an engineer within his own right, however, doing extensive Management and Engineering Consulting work in his spare time during the war years and for a number of years

following the war. He holds two degrees in Electrical Engineering, is a member of Eta Kappa Nu, taught evening classes in Electrical Engineering at SMU, at which time he authored a textbook: *Introduction to Practical Radio* (mostly math) published by The Macmillan Company in 1945. He is a registered Professional Engineer in the State of Texas, member of the National Society of Professional Engineers, as well as the Texas Society of Professional Engineers and has been active and held executive posts in each through the years.

He is a member of the Dallas Technical Club, member and active in both the IRE and AIEE, before their merger, and served two years on the national Board of Directors of the I.R.E., and is one of the founders of the Dallas I.R.E. section, being President several times. Headed the large annual electronic Southwestern I.E.E.E. show one year and is presently on the Board of Directors of the I.E.E.E. region of several states organization that controls the show and Chairman of the FCC North Texas Industrial Interference Committee for a number of years.

Durward has been active in amateur radio through the years, having obtained his first license in 1924. He has been an active contributor of numerous articles throughout this time. Being a DX man, Durward is a member of that fraternity that operates his transmitter only five or ten minutes for every hour that he operates his receiver. He is a member and past President of the West Gulf DX Club. During the declining sun spots Durward temporarily abandoned his nightly search for DX for things with more activity such as RTTY. He has been an avid phone DX man up until now, switching only to c.w. for those that never showed on phone.

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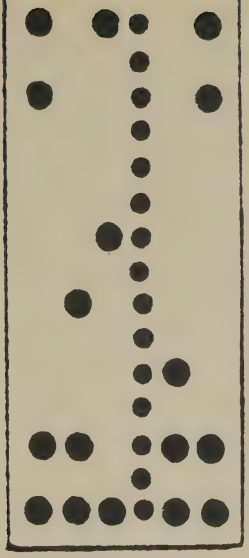

INTRODUCTION

AS WAS pointed out in the preface, *too little* has been published on the teletype subject through the years. Much of what was written has had a relatively small and restricted circulation. Furthermore, there has been little or no significant continuity between the limited material that has found its way into print.

For the first time, with the publication of this book, a person has an opportunity to pursue the subject of teletype and its application to radio (RTTY), from its beginning to its conclusion, without the need of additional study material and without any previous knowledge of the subject. This is an excellent opportunity for those with no previous RTTY knowledge or experience to become well versed in this fascinating subject. This is also an excellent opportunity for those already in RTTY work to fill in the missing gaps and to broaden their overall knowledge of radio teletype.

The author used very careful planning, not only in the technical level of the text but also in the selection, location and presentation of the material, throughout the book. For instance, it will be noted that both teletype machines and terminal units are *each* discussed at *two* different places in the book. The whole subject of RTTY revolves around these two all-important units of an RTTY system. Both subjects are too extended and complicated for the beginner to pursue either to its conclusion without first getting a good foundation on the whole system. On the other hand, it is necessary for the beginner to know a little something about teletype machines and converters, or terminal units, in order to get a better picture of the entire system. For that reason, the author introduces the reader to both subjects early in the book but leaves the detailed and extended coverage of these two subjects for the middle and latter half of the book. In each instance, the first or preliminary coverage of each of these subjects covered only basic fundamentals. The reader will surely agree that the final coverage of these two subjects leaves little to be desired, either in technical level or in details.

The technical level of the first part of the book was so gauged that a beginner, without previous knowledge of the subject, should have no difficulty in following the text as the author leads the reader logically step by step. Of necessity, as the whole subject of RTTY is covered, the technical level of the text is increased, bit by bit, so that in the end the author leaves little unsaid.

It is the hope of the author that this text will provide the incentive and act as a stepping stone for radio amateurs to try this fascinating and intriguing mode of communications. It is the author's further hope that this text will save the commercial or professional man countless hours of painstaking and diligent searching through technical literature (difficult to find) and that they will be pleasantly surprised to find so many answers to their questions all between the covers of one book.

History

It is generally conceded that the transmission and reception of the printed word between two distant points by means of electricity, all started in 1849 when such a system was established between Philadelphia and New York using a metallic circuit or telephone line. The system was far from perfect and it was not until 1906, when Charles L. Krum and Jay Morton developed a much improved machine, that the sending and receiving of the printed word seemed practical or destined to stay. The Morkrum Company (from *Mort*on and *Krum*), subsequently formed by these two men, hardly got "off the ground" until the Associated Press decided to try the Morkrum machine in 1915.

Present-day teletype systems probably owe ..ore to another event that took place about is same time. A German-born immigrant by e name of Edward Kleinschmidt came out h a teleprinter at about that same time. His chine showed that he was not only an elec- al genius, but a mechanical genius as well. Kleinschmidt Company and the Morkrum mpany went their separate ways until 1925 n they merged. This company was, in turn, ht in 1930 by the American Telephone Telegraph Company. The acquisition of patent rights by the AT&T was a natural to nurture the further development, im- ment and, of course, expand the use of ew and very practical and valuable means mmunications. Under normal circum- s, this would probably be the end of the or at least so far as Mr. Kleinschmidt oncerned. The inventive genius of Mr. chmidt would not rest. With the passage me, agreements and patents, Mr. Klein- idt got back into the business of design- developing and selling teleprinter equip- In fact, he still takes an active part in the activities of the present-day Kleinschmidt Company, although this company has now become a subsidiary of Smith-Corona Marchant Company.

As one would well imagine, people in other parts of the world also took up this work along the way. People were active, particularly in Germany, England and Italy. The Seimons and Halske, and Lorenz companies are active in Germany. Machines are made in Italy by Olivetti and in England by Creed.

Working in a day and age when distances between countries were more significant and isolating, it is understandable, but unfortunate, that speed standards in Europe and America differ slightly.

Sometime after World War II another American company, the Mite Corporation of New Haven, Connecticut, started making teleprinter machines.

Radio Amateur RTTY Pioneers

RTTY got its greatest boost during World War II as it was used by all of the signal services. It proved itself over and over again to both the army and the navy. Perhaps many hams, or would-be hams, learned about it for the first time during that war. Little wonder then that amateur radio teletype got started soon after World War II.

Space does not permit the listing of all of the pioneers as well as those radio amateurs that have made notable contributions to the art through the ensuing years. Yet, this account would be incomplete without listing at least a few. Neither by the listings, or by omission of others, does the author wish to set one group apart from the other. In his typical, unselfish way, as with other contributions to the communication art, the radio amateur has contributed much to the advancement of radio teletype communications.

Besides the teletype machine, there must be a converter, or terminal unit. All should be agreed that both W2PAT and W2JAV contributed much to the development of the converter or terminal unit. No pioneer worked more tirelessly than the late Boyd Phelps, WØBP, to advance amateur RTTY. He lost his life in an automobile accident in Mexico on a trip delivering a teletype machine to a fellow ham. One cannot overlook the years of work by Byron Kretzman, W2JTP, in writing the *CQ RTTY* column and the *RTTY Handbook,* and Merrill Swan, W6AEE, who published the RTTY Bulletin for the RTTY Society of Southern California for many years (published since 1967 by "Dusty" Dunn, W8CQ) and also made many other notable contributions. Across the country in Florida, Fred DeMotte, W4RWM, has done a notable job of publishing a similar bulletin for the Florida RTTY Society.

In the Midwest, Ray Morrison, W9GRW, staff engineer for Illinois Bell Telephone Company, Chicago, Illinois, typical of the Bell System hams, among his many contributions, has probably been responsible for more teletype machines finding their way into the eager hands of amateurs than any other ham. Al Corbin, W5KXD, a Bell System engineer of note from Dallas, Texas, is not far behind Ray in that respect. In addition, there is the ubiquitous Mr. Weithbrecht, W6NRM, Mr. Terminal Unit himself, an ardent experimenter, who has probably forgotten more about terminal units than most of us will ever know. Around the country, in the big league class, of course, is Victor Poor, K3NIO; Don Wiggins, W4EHU; Herbert Hoover, Jr., W6ZH; Frank Goude, K6IBE; Irving Hoff, K8DKC; Bruce

Harris, W5HCS; Bud Schultz, W6CG; and Leroy May, W5AJG.

Related Fields — Data Processing

In the beginning, it must have taken quite a bit of imagination and plain dreaming to conjure up a vision of a message being typed out by a machine and that same message being received by a similar machine and typed out at some distant point. The scope of this book covers this general concept.

It must, however, be dutifully reported to the reader that the state of the art has, during the last few years, extended far past this very simple dream or vision. For one thing, computers, (a related subject), for instance, have come into their own in the last few years. In the pre-war days, a computer was an oddity, a mysterious combination of mechanical and electrical wizardry. Today, computers are getting more common every day. They come in all sizes and for varied applications.

Closely associated with the word computer are the words data processing, data storing, *etc.* All kinds of new machines are being designed and manufactured and new applications and uses for them are being discovered every day. Some act like teleprinters and many of them look like the teleprinters covered in this book. To compare them and say that they are one and the same would be like comparing a modern automobile to a model fifty years old.

It seems that there are many code levels, dozens of codes and many different speeds. In some cases, the speed of transmission is fantastic. For instance, the Teletype Telespeed 750 is a high speed tape-to-tape equipment that has a speed of 750 words per minute, or 75 characters per second. Numerous companies have developed special machines that are especially adapted for data processing and also readily tie in with a computer. Such a machine is the Teletype Model 35 equipment. Another such machine is the Kleinschmidt Model 321 ADS High Speed Automatic Data Set. The manufacturer states that the ADS printer is a send-receive unit designed for operation in data processing systems utilizing 400 words-per-minute operation, or with conventional communications equipment operating at 60, 66, 75 or 100 words per minute.

The author will touch on the data processing subject and data processing equipment near the end of the book after he has thoroughly covered the teleprinter subject as applied to amateur radio.

1

RTTY BASICS

THE first question that might easily arise in connection with RTTY is, "Why Teletype?" We might counter with; "Why c.w?" or "Why voice?" The answer is that RTTY is a mode of radio transmission that is just as interesting, fascinating and as challenging as either radio telephony or c.w. If it's "action" that you want, then RTTY will surely give it to you. There is nothing that quite equals the strange fascination of a teletypewriter as it sits there and types out copy (look—no hands!) like magic. It's like having a second operator at your side. It's efficient—yes, almost a genius. There is little doubt about the truth in the statement, "Once an RTTY'er, always an RTTY'er."

It is nothing short of amazing that RTTY has not replaced more c.w. in the amateur bands than it has, especially in view of the fact that commercial radio telegraph companies abandoned c.w. for RTTY many years ago. It has been apparent to the author for some time that more radio amateurs would take up RTTY work if some of the apparent mystery (for the beginner) that surrounds it could be cleared up. It is the aim of the author to supply all of the basic links of RTTY from A to Z (as the title implies) and to do it in such a manner that it will fit together for the beginner in the most understandable sequence.

What strikes the newcomer to RTTY, is not only the strange and unfamiliar RTTY language, but the equally strange and unfamiliar extra pieces of equipment not found in other than the RTTY'ers shack. It is hoped that this book will not only bridge the gap between c.w. and phone to RTTY for the beginner, but also answer a few unanswered questions for those already in RTTY. If the first part of this book appears oversimplified to the regular RTTY'er, just remember that we all asked some basic questions when we first started out in RTTY work. Too many relatively simple answers to simple questions, so far as RTTY is concerned, are hard to come by when one is just beginning. I can't resist the temptation to make a point on the language problem before covering the subject from A to Z. Here goes: "The space pulse is always on the low side when on f.s.k. and high when on a.f.s.k., but of course you may invert when you tune in the signal, which is ok. unless your b.f.o. is already set on the opposite side. Everything clear?"

Teletype Speed

The standard speed of teletype machines used for amateur RTTY is 60 words per minute (if you can type that fast or if you are using a perforated tape), receiving or sending. The operator may be typing at a rate of only 30 or 40 words per minute but each character, as it is typed, races through the teletypewriter at a rate of 60 words per minute. The delay is in the time elapse before the operator strikes another key. One cannot make the machine write faster than 60 words per minute even if the operator can type much faster—say 70 or 80 words per minute. The machine makes mistakes when the typist exceeds 60 w.p.m. This is a lot faster than c.w. unless you are one of those few and far between high speed c.w. operators. Even a poor typist can manage a thirty or forty words per minute typing speed after a little practice.

Morse Code

The Morse Code as used for c.w. is binary which simply means that it is formed from two conditions—On or Off. Teletype transmissions work the same way. The c.w. Morse Code is formed from various combinations of dots and dashes with the dash three times as long as the dot. Naturally, there has to be a short space (of same length as the dots) between the dots and dashes in order for each character to be formed such as in the forming of the letter "C". Thus: dash-space-dot-space-dash-space-dot. Likewise, there must be a slightly longer space between groups of characters forming words.

It should be readily apparent, from the above, that the time length of the Morse Code characters vary over a wide range. The letter "E", for instance, has a single dot whereas "zero" with five dashes has the equivalent of 19 dots. In other words, the "zero" character is 19 times longer than the "E" character.

It is also apparent that the time length of the dots and dashes and the subsequent characters they form will vary with the speed of transmission. In other words, all three will be three times as long at 10 words per minute than at 30 words per minute. This discussion of the Morse Code makes it pretty apparent that, although it works well for the human ear, it doesn't appear to be the proper approach for a code to operate a mechanical device such as the teletypewriter. In the first place, a "machine code" must provide some means whereby the receiving machine can be synchronized with the sending machine. This is not only necessary from character to character but *for all elements of each character.* A code whose character lengths vary as much as 19 to 1 certainly does not readily lend itself to adaptibility as a machine code.

Teletype Code

From the very beginning it was apparent that a different approach, other than that of the Morse Code, was necessary in designing an appropriate code for teletypewriter operation. In describing the mechanics of the Morse Code in detail, the stage is now set to show the three principal ways in which the teletype code is different. 1. The teletype code uses dots only (no dashes). 2. The space (same length as the dot) is as much a part of the code as the dot. In other words, the characters are formed altogether from dots and spaces of same time lengths. Furthermore, the length of the dots and spaces do not vary since they are fixed at 22 milliseconds for the standard amateur teletype fixed speed of 60 words per minute. 3. All of the letters, figures and symbols of the teletype code are of the same time length (110 milliseconds plus a 22 millisecond start space

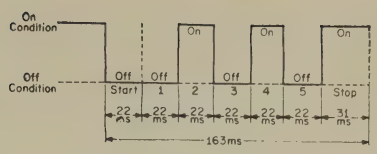

Fig. 1.1—Pulse sequence of the letter "R" in the Teletype Code is shown above. Each letter, figure, or other character starts with a 22 ms *"Space"* (Off) pulse and ends with a 31 ms *"Mark"* (On) pulse. The arrangement of the On *(Mark)* and Off *(Space)* 22 ms time elements (5 in all) determines the particular character that is formed. All of this is based on the standard amateur RTTY fixed speed of approximately 60 words per minute.

and a 31 millisecond stop pulse, making a total of 163 ms (See fig. 1-1 and 1-2). Each character has five elements (dots and spaces) plus the 22 ms start space and the 31 ms stop pulse.

Figure 1-1 shows the pulse sequence of dots and spaces, each 22 ms in length, of the letter "R" in the teletype code. The 22 ms sync or start pulse (Off) is also shown as well as the 31 ms stop pulse (On). The arrangement of the five elements that form the letter "R" is, space-dot-space-dot-space.

One may wonder about the 22 milliseconds start space as well as the 31 millisecond stop pulse since, obviously, this considerably lengthens each character, in fact, almost fifty percent. Actually, the 22 millisecond start space is for synchronizing the sending machine with the receiving machine. The 31 millisecond stop pulse has a two-fold purpose. First, it provides for adequate time, after a character is sent, for the "sending" mechanism of the sending machine as well as the "receiving" mechanism of the receiving machine to properly position themselves for the transmission of the next character. Secondly, the stop pulse also provides a closed circuit for the teletype machine so that it will not "run open" when the machine is in a rest position (when no character is being sent). More on this later.

The teletype code is shown in the bottom line column of fig. 1-2. Figure 1-2 also shows a perforated tape of the alphabet, figures and other characters as they might have been punched out by the tape perforator of the Teletype Model 19 tape set. The string of small holes, marked FEED, fits the tape drive sprocket wheel of the machine that originally punched the tape, including these drive holes, as well as the sprocket drive wheel of the various machines that may be used to transmit the tape. It will be noted that, besides the alphabet, numerals, question mark, colon, *etc.* that there are special characters for word spacing, carriage return, line feed, figures and letters. These last several are for the complete

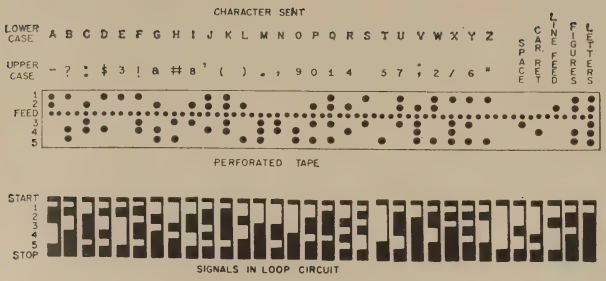
CHARACTER SENT
LOWER CASE A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
UPPER CASE - ? : $ 3 ! & # 8 ' ( ) . , 9 0 1 4 5 7 ; 2 / 6 "
SPACE
CAR. RET
LINE FEED
FIGURES
LETTERS
1 FEED 2 3 4 5
PERFORATED TAPE
START 1 2 3 4 5 STOP
SIGNALS IN LOOP CIRCUIT

Fig. 1.2—Teleprinter Code.[3] The perforated tape shows the exact arrangement of dots (indicating On) and spaces (absence of dots) for all characters of the Teletype code. The last column graphically indicates the relation between dots (On) and spaces (Off) in producing the various characters of the five element teletype code.

automatic operation of teleprinter in printing received copy. The bottom line graphically indicates the relation between dots (On) and spaces (Off) in producing the various characters of the five element teletype code as well as the start space (Off) and end or stop pulse (On).

Figure 1-3, (A), (B), (C), and (D) shows two types of tapes in general use by radio amateur RTTY'ers (the two top sets). The tapes are punched from the same blank paper tape and differ only in that the chads are punched clear of the holes in one type and in the other type the chads remain attached to the side of the holes by a sliver of paper. About 90% of the hole circumference is punched, leaving the chad attached by the remaining 10%. This last type makes it possible for the message to be typed on the punched tape.

RTTY Speeds

It has been pointed out in fig. 1.1 that it takes 163 milliseconds or 0.163 seconds to complete one character before the teletypewriter or teleprinter is ready for the next character. Also pointed out was the fact that each code element (the dots) consumed 22 milliseconds or 0.022 seconds. Thus in one second 1/.022, or 45.45 dots can be transmitted.

The 22 milliseconds dots are called "Bits" and, as stated above, 45.45 Bits per second can be transmitted. The 45.45 code elements transmitted in one second is called a "Baud."[2]

Since the pulse sequence of each letter consumes 163 milliseconds, the maximum number of letters per minute would be equal to, 1 sec/.163 × 60 = 368. Thus 368 operations per minute (o.p.m.) are possible

For RTTY work, a word is considered to average five letters. Since the five letter word must be followed by a space each word is considered to have six operations.

Since we indicated 368 operations per minute are possible and each word averages 6 operations we have 368/6 or 61.33 words per minute. This number of words, 61.33 w.p.m., cannot actually be transmitted since there are other non-printing functions such as Shift, Line Feed and Carriage Return which each take up one operation. The result is a maximum speed of 60 w.p.m.

It might be pointed out, that 60 w.p.m. is by no means the only teletypewriter speed developed or in use today. In fact, there are quite a number, at least eight to my knowledge and perhaps more. The speed varies with the users —Bell system, Western Union, Europe and various military, to mention a few.

One of the reasons that teletype machines are becoming available to amateurs in greater numbers is because of the tendency of commercial users to use the higher speeds such as 75 w.p.m. and 100 w.p.m.

The speed that is in general use in Europe is that of the Consultative Committee on International Telegraph (C.C.I.T.) which is 66.67 words per minute. Unfortunately, the receiving shaft speed of this code is 461.5 r.p.m. as compared to a receiving shaft speed of 420 r.p.m. for the 61.33 w.p.m. U.S. amateur code (one of the U.S. Bell system speeds) and these codes are not compatible. This creates a problem when an American amateur is using one of the 61.33 w.p.m U.S. Bell system machines and a European amateur is using a machine using the C.C.I.T. standard. Obviously, the speed of one of the machines must be modified before the two amateurs can communicate with each other.

Machine Speeds

The F.C.C. rules require that a machine transmitting speed of about 60 w.p.m. be used. Machines designed to operate at any appreciably different speeds must be converted to the 60 w.p.m. speed before they can be used on the American radio amateur bands. There are two reasons for this. One is to satisfy the FCC requirement and the other is to be able to talk to

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The term "Baud" comes from one of the early developers of the five unit start-stop teletype code, Mr. Baudot.

[3]Kretzman, B., "An Improved Radioteletype Converter", *CQ*, April 1958, page 44.

the other amateurs. The machines must operate at essentially the same speeds (w.p.m.) in order to communicate.

Up to this point in referring to the speed of teletype machines, the author has talked in terms of words per minute such as you would speak of automobile travel in miles per hour. Like the car, a teletype machine has a motor and gears which have a bearing on the speed. In the case of the teletype machine it is powered by a synchronous electric motor of fixed r.p.m. and the speed of the teletype machines main shaft (called the receiving shaft) controlling the printing mechanism is determined by the fixed gears connecting the motor to this shaft. Naturally, the C.C.I.T. speed of 66.67 w.p.m. requires a considerably higher receiving shaft speed than does the American Bell system speed of 61.33 w.p.m.

The speed of the receiving shafts of the two machines must be essentially the same and the code speeds in bauds should also be the same for two machines to be compatible. For instance, the U.S. Western Union 65 w.p.m. machines and the U.S. Bell 61.33 w.p.m. machines are compatible since each have a receiving shaft speed of 420 r.p.m. and the code speed of each is 45.45 bauds. The difference in speed is due to the fact that the stop pulse of the Western Union code is 22 ms as compared to 31 ms for the Bell System machine code.

Machines that operate at 60 w.p.m. or at speeds that can be readily converted to 60 w.p.m are not as easy to come by in foreign lands since, invariably, the commercial users in such lands use speeds other than the U.S. Bell system where most of our machines come from. It must be realized in discussing the various transmitting speeds, that average speeds or average w.p.m. are meant since we are dealing with machines or mechanical devices.

Code Nomenclature

The five unit code is often referred to as five channel and as five level with all three meaning the same thing. The units themselves are often referred to as "bits" and the bits per second is the baud speed as already covered. It is 45.45 bauds for a speed of 61.33 w.p.m. (rounded off to 60 w.p.m.) It will be noted that in speaking of the aforediscussed code as a five unit or five level code, we are referring to the five levels of "intelligence changing portions" of the total of seven transmitted portions that make up each character. The "start" of every character is always a *space* and the end of every character is

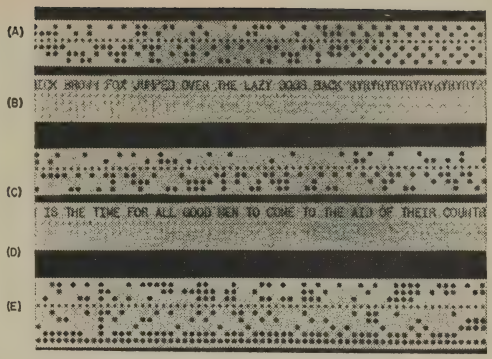


Fig. 1.3—Picture showing perforated teletype tapes. Tapes A, B, C, and D are of the 5 level code as used by radio amateurs. Tape E is an 8 level code used by Bell Telephone. Tapes A and C were perforated by the tape perforator of a Model 19 "Composite Set" and a Model 14 typing reperforator perforated tapes B and D.

always an On pulse, so it is only the five equal length time segments (22 ms for the amateur 60 w.p.m. Code) in between that change in forming the characters. Therefore, the reference to it as a five unit code.

Nevertheless, the code is sometimes referred to by its entire character make up. In this case they take the entire character length which is 163 ms and divide this by the time length of each of the 5 middle units (22 ms) to determine the code units. Thus $163/22 = 7.42$ units. For the U.S. Western Union code with a character length of 154 ms we would have $154/22 = 7.0$ units. For the 100 w.p.m. U.S. Code with a character length of 100 ms we would have $100/13.47 = 7.42$ units.

Frankly, the author prefers to think of all of these codes simply as 5 level codes. There is a good reason for this. There are codes of other levels such as an eight level code in which there are now eight character forming time segments that may be either space or pulse in forming the characters as in the aforediscussed 5 unit codes. Eight level codes and others have varied applications in advanced telephone system services, data processing, computers and the like. An eight level code is shown in fig. 1.3 (E) as a basis of comparison with the four samples of the five level code also shown in fig. 1.3. As radio amateur RTTY'ers, we are only interested in the 5 level codes herein discussed and particularly the 60 w.p.m. one since it coincides with the FCC requirement and the machines available for our use.

2

THE TELETYPEWRITER

It must be realized that the teletypewriter is a mechanical device. However, it is a most ingenious device as well as a machine of high precision, not only in design and manufacture and in operation as well. The word "Teletype" has become as synonymous with RTTY as the word "Kleenex" has for tissues. The word "Teletype" is a registered trade mark of the Teletype Corporation of Chicago. This company has dominatd this field in America for many, many years. Two other companies in this country are now in the field.

For many years Teletype machines that became obsolete or else too worn for further commercial use were broken up and disposed of as junk. Through the untiring efforts of numerous influential hams, many of them in the employment of the Teletype Corporation and the various Bell Companies, the Teletype machines began to find their way into the hands of the radio amateurs. Not only were the machines made available but they were released at a nominal sum which just about covered the shipping and other handling charges. Amateurs are required to give their word, by signed waiver, that the machines will be put to the service for which they are released (amateur radio) and not to any commercial use. It is hoped that these generous privileges are never abused.

Fig. 2.1—Teletype Model 15 page printer used for both Transmit and Receive functions.

Do not contact your local telephone company or the Teletype Corporation to ask about the availability of a machine. In the first place, all of the companies don't necessarily participate in the plan of making the machines available to the amateurs and furthermore, those that do, of necessity, and from a practical standpoint, must do so through reliable and established organizations.

I believe that in most instances, the Bell machines are distributed to the hams through a local or state RTTY society. It is suggested that you first check with your local amateur radio club to see if there is an RTTY society in your city or state.

A few machines have found their way into the open market. Some of these have been damaged machines that either need repairing or have been repaired. As a rule, such machines cost much more and you don't always know what you are getting. It requires not only special tools, but special skills to work on a tele-

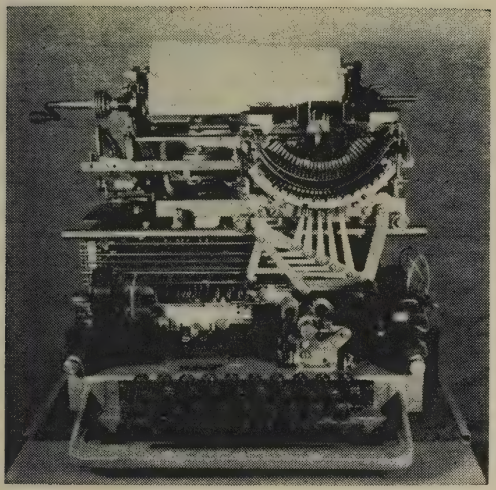


Fig. 2.2—Interior view of the Model 15 page printer.

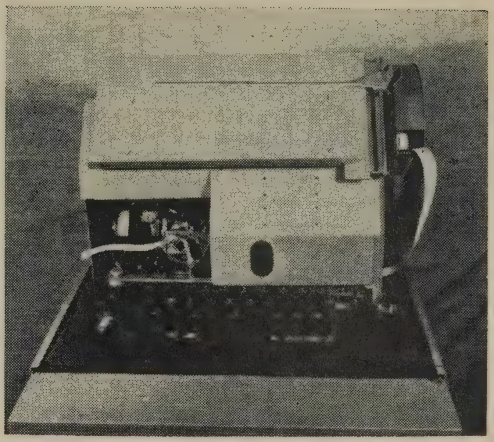


Fig. 2.3—Teletype Model 14 typing reperforator. This unit performs the same function as a page printer but on a tape rather than a page.

type machine; therefore, this is not usually done by the average ham. On the other hand, there have been a few hams who have repaired machines by actually fabricating the parts that were missing or needed replacing. As a rule, it is better to consult with a fellow ham who is familiar with the machines.

Machine Descriptions

There are two general types of Teletype machines. They are the "Page printer" and the "Tape printer." The page printer prints on a sheet about the width of ordinary typewriter paper except the paper comes in rolls about four to five inches in diameter. The paper is also available in a continuous length but folded into a box approximately 9" long by 10" high. When the folded paper is used, the box sits on the floor in back of the machine.

Most of the tape printers in amateur use are of the 11/16" wide tape variety (in rolls about 6" in diameter) such as used by the Model 14 typing reperforator. However, there is narrow tape about 3/8" wide in limited use.

The following discussion covers the most commonly encountered machines. The page printers are used in the Receive and Transmit function. In Receive they type the message out in page form. In Transmit they form the proper code sequences for transmission as the desired keys are hit. The transmitted message may or may not be printed by the machine as the operator chooses.

The Model 12 page printer is quite old. Very few suffering YL's would allow this infernal noisemaker in the house for long. The OM breathed a sigh of relief when the Model 26 became available. However, it too is now rather old and is fading from the amateur RTTY scene. The author would advise all those entering the RTTY field to try for something better than a Model 12 or even a Model 26 if at all possible.

A more recent page printer is the Model 28 (the Cadillac variety) which is not yet generally available for amateur use (just forget about it for a few more years). Another page printer available is the Model 15, part of the Model 19 Tape set which will be discussed shortly. The Model 15 is shown in figs. 2.1 and 2.2, and is the unit the amateur should try to obtain.

Model 14 Typing Reperforator

If one can afford another machine besides a Model 15 then the logical one to try to obtain next is the Typing Reperforator, Model 14. It is much like the page printer but works with tape rather than pages. It serves both the receive and transmit functions. The Model 14 Typing Reperforator is shown in figs. 2.3 and 2.4.

The Model 14 could be obtained instead of the Model 15 page printer except for the fact that you would be receiving on a tape. Actually, a page printer is more practical. If you had only a tape printer you would always be knee deep in tape.

The Model 14 typing reperforator with keyboard is so called because it punches or perforates the tape, printing the message on the tape at the same time. This function is the same regardless of whether you are sending or receiving on this machine. In other words, you *cannot* turn off the punching function and only print on the tape. It might be noted that there is little or no point in having this particular machine unless you also have a "tape reader"

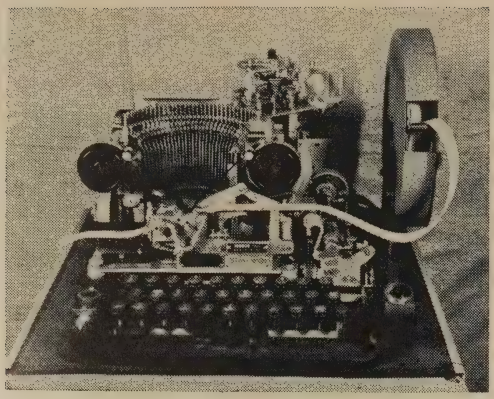


Fig. 2.4—Interior view of a Model 14 typing reperforator.

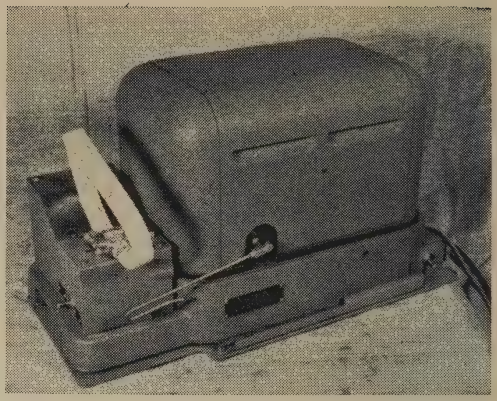


Fig. 2.5—Teletype transmitter — distributor Model 14 used to transmit pre-punched tapes at speeds up to 60 w.p.m. The closed loop tape repeats the message until the machine shuts down.

such as the model 14 Transmitter Distributor covered a little later.

The Model 14 Typing Reperforator punches a chadless tape or one in which the chads are not completely severed from the tape. A small part of the leading edge of the chad is left attached to the tape. Note that a chadless tape is one that *retains* all the chads and because the tape is chadless, it is possible to both print and perforate at the same time. This makes it possible for the operator to monitor the tape as shown in figs. 1.3B and 1.3D. It also permits quick identification of tapes stored for future use.

Model 15, Plus Perforator Transmitter

The Model 15, Plus Perforator Transmitter is a Model 15 page printer plus a tape perforator and a character counter that tells the operator when to press the LINE FEED key to start a new line at the receiving page printer. This composite set of equipment is designated as a "Model 19 Tape Set" by the Teletype Corporation. More on this in just a moment.

Model 14 Transmitter Distributor

The Model 14 TD receives prepunched tapes of the chadless or chad type. It is used strictly for transmitting purposes. This machine is shown in figs. 2.5 and 2.6. The covered view is shown with a continuous loop tape used to repeat a prepared message. The tapes are transmitted at 60 w.p.m. by the TD machine even though the operator may have originally perforated the tape at a much slower speed. For this reason, the machine is used to transmit CQ's, antenna layouts, station descriptions, discussions, and other routine material as well as contest sequences that can be prepared in advance on a perforated tape. This takes some of the work out of operating as well as speeding up things if you can't type at 60 w.p.m. In fact, you would be amazed at the *work* that some operators go to in this respect to get out of *work!* With a battery of TD's or similar machines that operate from push-button controls, individually or sequentially, an operator can load all of the machines with prerecorded data and carry on a QSO while reclined in his chair. C.w. was never like this! Some don't even have to operate a manual send-receive switch—this is done automatically when sending ceases.

Some operators (who, naturally, have more than one machine) watch the copy coming in on one machine and perforate the answer on tape on another machine at the same time. When the other operator stands by, the perforator tape is fed to him at a steady 60 w.p.m. clip. During this time the now sending operator can twiddle his thumbs, go get a drink of water, or else think up more skulduggery for the next round!

Model 19 Tape Set

Finally, there is the Model 19 Tape Set. Shown in figs. 2.7 and 2.8, it consists of a Model 15 page printer, a Model 14 Transmitter Distributor, a perforator-counter and a heavy duty power supply.

Examination of fig. 2.7 shows the Model 15 page printer on the right. In the center is the perforator-counter. The tape feeds through the perforator-counter into the Model 14 Transmitter Distributor. The power supply is located on the shelf below the equipment.

The operator has several options in the operation of the Model 19 tape set. There is a three position switch on the front, just above the right hand side of the keyboard. The three position switch, from top to bottom, is designated: KEYBOARD, KBD. & TAPE, and TAPE. It is possible to be receiving RTTY copy that is be-

ing printed on the page printer while you, at the same time, are operating the keyboard and perforating a tape, with these two functions being independent of each other. This is with switch in the TAPE position. By placing the function switch in the KBD & TAPE position, it is now possible to write on the keyboard thereby perforating a tape and at the same time the page printer is also printing out the message. Counter does not function in this position and you must watch the page printer to see when you come to the end of a line. Finally, you may throw the function switch to the KEYBOARD position and the machine will function similar to a Model 15 in that the tape punching or perforating mechanism does not function but the keyboard and page printer do function. Writing on the keyboard prints on the page printer.

The counter is to let the operator know when he has punched enough characters on the tape to equal a line on a page printer. A warning light, behind the counter, comes on when 66 characters are hit. He should then punch the CARRIAGE RETURN character and the LINE FEED character to be cut on the tape. Otherwise, when he later transmits the tape, on the TD unit, all amateurs with a page printer would see their machine type to the end of a line at the right hand side of the page and start printing all subsequent characters on top of the last character in the line. In this case, the receiving operator would make a dive for the CARRIAGE RETURN key and LINE FEED key on his own machine; otherwise, he would miss the rest of the message.

It might be well to observe, at this point, that the carriage must return from the end of a line to the start of a new line in the same time that it takes to print one letter or any other character (0.163 sec.). Furthermore, the paper must be rolled up one line by the line feed operation at the same time. These are pretty fast mechanical operations! If these two operations don't function properly, there is no telling where the next letter will print.

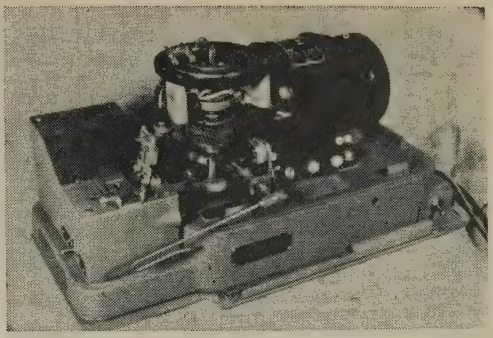


Fig. 2.6—Interior view of a Model 14 transmitter distributor.

Automatic Carriage & Line Feed Kit

It is possible to obtain an automatic carriage return and line feed kit for a Model 15 page printer. The advantage of this is that the letters do not pile up at the end of the line if the machine fails to receive the carriage return character or if the transmitting operator fails to send it. You can adjust the mechanism for the carriage to return at whatever predetermined point you desire. It is best to set the automatic carriage return so that it takes place a few spaces past the point where the sending operator should have put this function. Of course, you don't ever know for sure if the sending operator has failed to hit the CARRIAGE RETURN and LINE FEED keys or whether he faithfully sent them and your machine failed to receive these two functions. Anyway, the end result is the same and the kit for this automatic feature eliminates this problem.

The kit creates another situation; suppose that the sending operator forgets to press the CARRIAGE RETURN key and LINE FEED key at the proper time and this is automatically done by the receiving end machine and then one or two characters later the sending operator suddenly remembers and sends both these functions. Obviously, your machine performs these two functions all over again, starting another

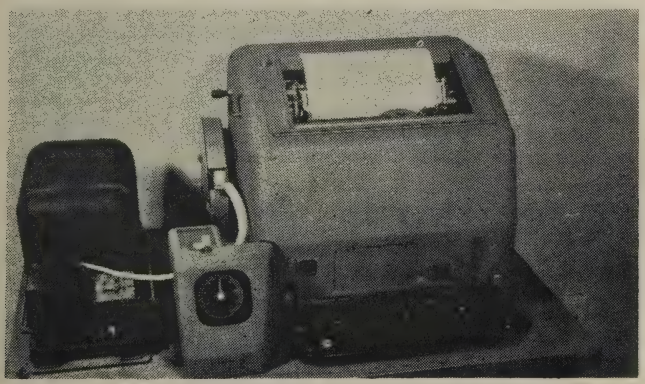


Fig. 2.7—Teletype Model 19 tape set. The unit on the right is a Model 15 page printer. The left unit is a Model 14 transmitter distributor. The center unit is a perforator-counter, the function of which is explained in the text.

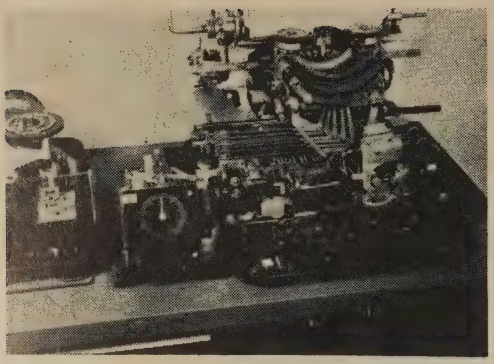


Fig. 2.8—A Model 19 tape set with all covers removed.

line even though it has only printed a character or so on the new line. There is one other point in connection with the use of the automatic line feed and carriage return feature on your machine. These two functions more than often occur during the time that a word is being sent, or more specifically, during the time that one character is being sent. That character is not usually lost but prints on the next line and anywhere from one-third to two-thirds back across the page.

Keyboards

Various keyboard arrangements are encountered, depending on the commercial use or service the machine was put to before it became available for radio amateur use. Old keytops can be pulled off and new ones snapped on in their place. The type slugs may also be changed but they are more difficult to change as they are soldered to the typing arm.[4]

Most hams get the RTTY keyboard arrangement shown in fig. 2.9. Naturally, the typing arm is going to print whatever character slug is soldered to that arm. A certain amount of confusion can result if all hams don't get around to changing not only the key caps but the slugs, as well on the corresponding typing arms so that their keyboard and slugs coincide with the standard keyboard as shown in fig. 2.9. Both the key caps and slugs are available

[4]RTTY Column, *CQ*, Jan. 1962, page 70.

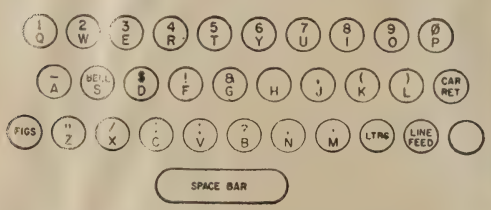


Fig. 2.9—The most commonly used RTTY keyboard arrangement.

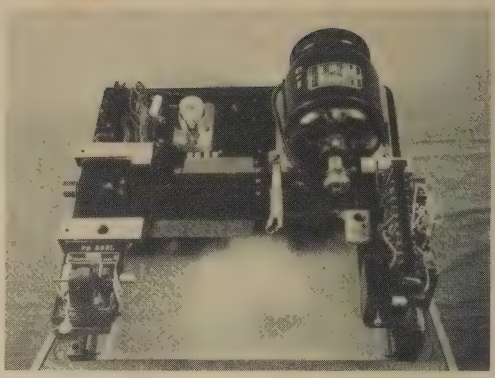


Fig. 2.10—Model 15 base showing the synchronous motor.

from a number of amateurs around the country as well as other sources at a very nominal cost. One such source that the author has used is W4NZY.

It will be noted that there are only three rows of keys instead of the customary four rows to be found on a regular typewriter. When changing from sending letters to sending figures, the FIGS key must first be pressed. Like wise, the LTRS key must first be pressed when changing from figures back to letters. Pressing the space bar will also switch most Model 15 machines from figures to letters.

There are certain operating procedures and courtesies to be observed and practiced such as pressing the CARRIAGE FEED and LINE FEED keys twice each to be sure that these two functions are properly carried out by the receiving operator's machine. It is also a good idea to also press the LTRS key at the same time just to be sure that the machine at the receiving end continues to print letters at the start of a new line instead of switching over to printing FIGS as they have been known to do. This is partic-

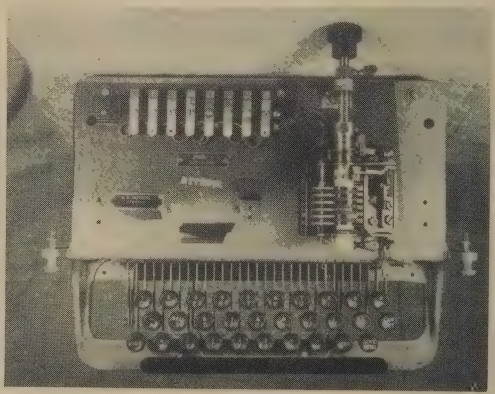


Fig. 2.11—Model 15 keyboard. The transmitter mechanism may be seen on top, to the right.

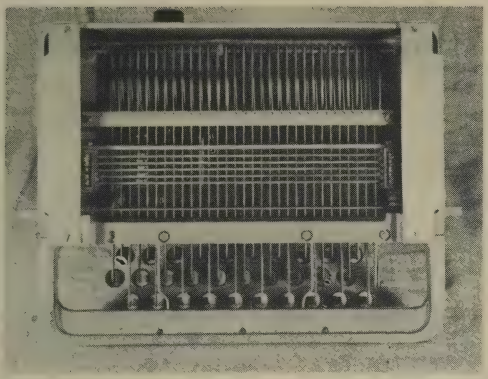


Fig. 2.12—Bottom view of the Model 15 keyboard showing the five crossbars.

ularly important when conditions are such that perfect copy is not being made.

Machine Basics

As stated before, the teletype code is binary which simply means that it is formed from two conditions, On or Off. A teletype machine works on that principle. The receiving mechanism (mechanical and electrical) responds to an On and Off d.c. signal. One's thoughts, at this point, may wander to how the r.f. or a.f. signals operate the machine. The answer is simple—they don't—that is, not directly since the machine *is* a d.c. operated device. That part will be easier to understand after a more basic knowledge of the machine itself is gained, so let us pursue further some of the basics of the Teletype machine.

A machine is chock full of mechanisms, but the most important basic functional ones are: (1) keyboard; (2) synchronous a.c. motor; and (3) receiving mechanism (selector magnet and associated typing unit). As a matter of fact, the Model 15 machine is mechanically assembled on that basis. First, there is the machine base shown in fig. 2.10. The motor mounts on

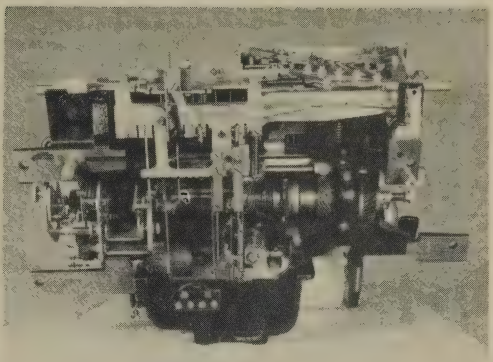


Fig. 2.14—Bottom view of the Model 15 receiving mechanism.

the base at the rear and to one side and is also shown in fig. 2.10.

The keyboard and its associated transmitter (mechanical parts with electrical contacts) fits into the front of the base and is held in place with knurled screws. Figure 2.11 shows a close-up of the top of the keyboard alone and fig. 2.12 shows a close-up of the bottom of the keyboard.

The receiving mechanism containing the selector magnet, selecting parts and the printing mechanism (the remaining part of the machine) is built as one unit and fits over the keyboard where it, in turn, is fastened down with knurled thumb screws. An inspection of figs. 2.2, 2.10, and 2.11 will show how the receiving mechanism fits into place over the keyboard. Figures 2.13, 2.14, 2.15 give top, bottom and left side views of these, the most complicated portion of the Model 15 machine. The selector magnet may be seen in the lower left foreground of fig. 2.15. Its associated selector mechanism is adjacent and to the right. The range finder (to be discussed later) is in the center bottom foreground. It is the flat

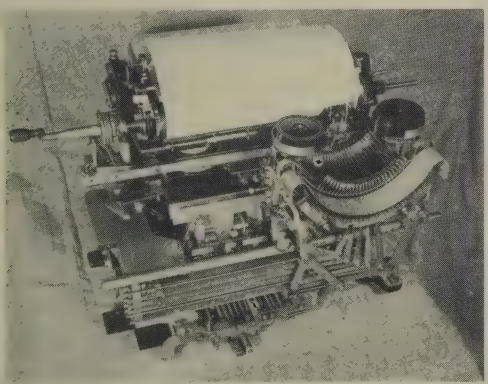


Fig. 2.13—Top view of the Model 15 receiving mechanism.

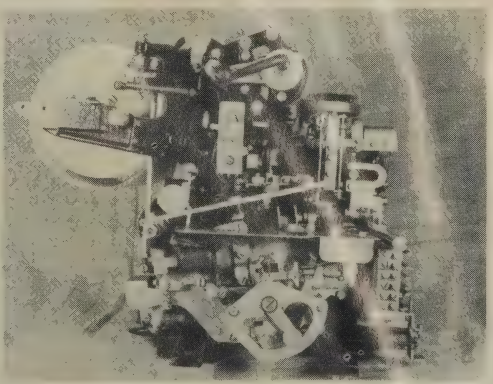


Fig. 2.15—Left side view of the Model 15 receiving mechanism.

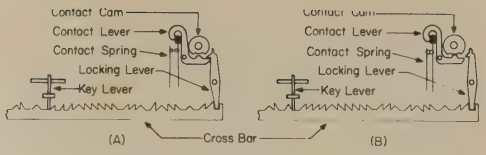


Fig. 2.16—Cross-section view showing how the key lever actuates the cross bar which, in turn, actuates the locking lever to open or close the associated switch which rides on the cam.

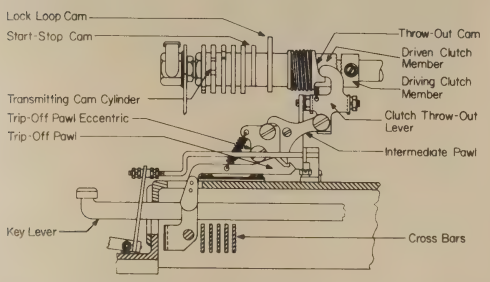


Fig. 2.17—Cross section view of the keyboard showing the relative positions of the key levers, crossbars and the transmitter mechanism atop the keyboard.

plate with a half-moon cut-out and adjustable arm. The three basic units as described above may be separated from each other in a matter of seconds. The motor unit provides the power to operate the various parts of the other two units. Each unit is supplied with a drive shaft and gear so that they mesh properly as each unit is put in its proper place. See figs. 2.10, 2.11 and 2.14. Care should be exercised when meshing the gears to avoid damage to the fiber gears.

Keyboard Operation

As previously stated, the teletypewriter keyboard is similar to that of a standard typewriter except it has only three rows of keys instead of four, and the keyboard function and printer function are mechanically separated.

The type basket of a Teletypewriter machine uses type bars not too different from those of an ordinary typewriter. However, the type bars are not mechanically connected to the keyboard keys as in an ordinary typewriter.

An idea of how the keyboard works can be gained by looking at its bottom side and its associated mechanisms in fig. 2.12. The first thing to note is that there are five crossbars extending crosswise (at right angles) to the key bars and from side to side thereby extending under all the key bars. The crossbars have odd shaped sawtooth type notches along their top edges under the key bars. The crossbars are each free to move (lengthwise). When a key

Fig. 2.18—Top view of the Model 14 typing reperforator base and keyboard.

is depressed, the key bar presses downward into the slots of all five of the crossbars. If the slot under the key bar is open, then the crossbar is not forced to move. If the slot has a slanting side under the key bar, then that crossbar is forced to move longitudinally. This is shown in fig. 2.16. The crossbars move or do not move, depending on the character of the slot of each crossbar under the key bar that is depressed.

Transmitter Mechanism

The next thing to note is the transmitter mechanism on top of the keyboard unit shown in fig. 2.11; it is on the right side. This unit has a drive shaft with a clutch and a distributor with six cams. A metal finger with an associated make-break switch rides on each cam. Five of the switches are normally open. These are the ones that form the five teletype characters. The sixth switch is normally closed and provides for the 31 ms stop pulse. The cams are circular discs about ⅛" thick and about ¾" in diameter. The five code cams have slots of equal length that allow their associated switch fingers to fall in permitting the associated switch to stay closed for 22 ms. The cam slots are placed around the circumference of the distributor so that the next one starts where the previous one ended with the exception of the 31 ms cam slot and the first 22 ms cam slot. There is a 22 ms space between these two. This accounts for the complete circumference of the circle for one rotation. This is illustrated in fig. 2.17.

The next thing to note is that each crossbar is connected to a lever extending to the transmitter distributor on top of the keyboard frame. This is also shown in fig. 2.16. The code signal notches on the crossbars allow the levers to operate and lock the metal fingers into place on the transmitter distributor to operate the electrical switches. Obviously, these levers position

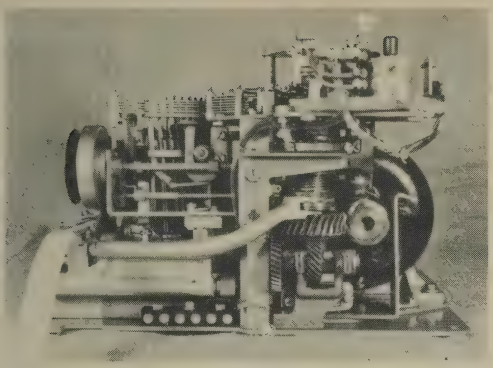


Fig. 2.19—Right side view of the receiving and reperforating unit of the Model 14.

themselves simultaneously, in accordance with the crossbar notches, the instant that a key is pressed. In popular present day scientific language we would say that the information was stored.

At this point, the transmitting distributor (the cam cylinder) is released to make one revolution being actuated by the pressed key. With the turning of the distributor, the d.c. pulses are accurately formed or transmitted in correct time relationship to each other. Likewise, they are received by the selector magnet of the receiver, stored in its mechanism, then released in proper sequence and time relationship to the printer mechanism. The transmitter distributor turns one revolution for each and every character transmitted and at the same time it also sends the 31 ms stop pulse as well as providing for the start space of 22 ms. The time for one revolution is 163 ms or 0.163 seconds. Thus, $1 \div 0.163$ equals 6.133 revolutions or characters per second or 6.133 X 60 seconds equals 368 r.p.m. which is the speed of the distributor at 60 w.p.m.

Model 14 Transmitter Mechanism

The Model 15 machine just described and the Model 14 typing reperforator are only basically similar. Figure 2.18 shows the base and keyboard of the Model 14 typing reperforator. The transmitter mechanism is on top and in the right foreground. Figure 2.19 shows the right side of the receiving mechanism. It will be noted that the motor is associated with this unit whereas it is mounted on the base of the Model 15 machine. Figure 2.20 shows a close up view of the selector magnet and associated mechanism as well as the range finder.

Model 14 Transmitter-Distributor

The Model 14 transmitter-distributor is equipped with five small sensing pins arranged in a row at right angles to the length of the tape. Perforated holes indicate "On" and the absence of a hole indicates "Off". The perforated tape does not pass over the row of pins at a uniform speed. To the contrary, the tape moves in jumps or spurts. A perforated character is positioned over the pins. Where there is a perforated hole the corresponding pin moves up through the hole closing an electrical contact. Naturally, any pin that has no perforation above it is unable to move up so that contact remains open. A closed or On contact means *mark* and an open or Off contact means

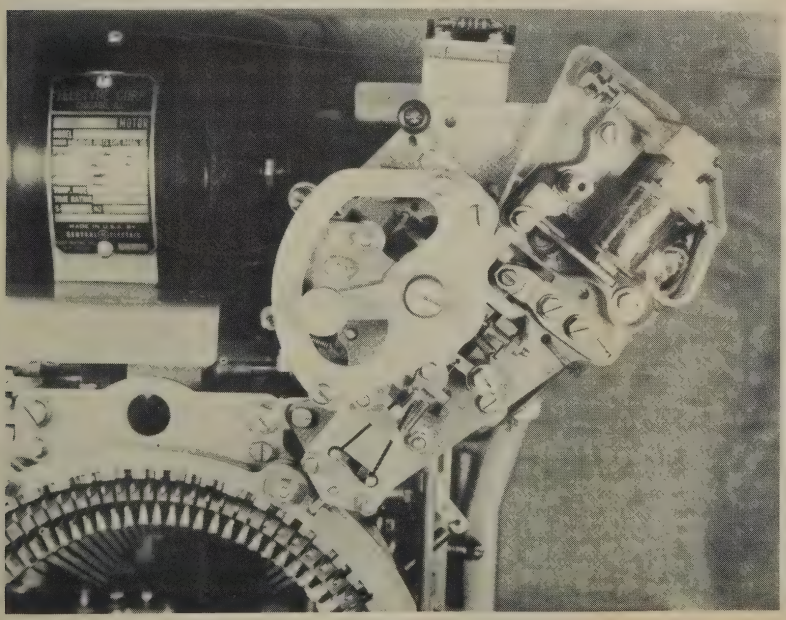


Fig. 2.20 — Close-up view of the selector magnet and associate mechanisms as well as the rangefinder of the Model 14 typing reperforator.

space. The tape remains stopped long enough for the closed and open contacts associated with the five tape sensing pins to be transmitted in proper time sequence by the distributor plate which can be seen in fig. 2.6. The distributor plate makes one complete revolution for each character and stops. The time for the complete transmission of each character is 0.163 sec. or 163 ms for a speed of 60 w.p.m. as previously noted. The tape then jumps forward almost instantaneously to the position of the next perforated character on the tape and the process is repeated.

Receiver Printing Mechanisms

At this point it has become obvious that the actual teletype code sending mechanism is nothing more than five simple make-break switches that either close or stay open when the 22 ms time interval for each to function, comes by. They make and break a supply voltage of 120 to 200 v.d.c. at either 15 to 20 ma or 50 to 60 ma of current. From this it is safe to surmise that the main part of the receiver unit is nothing more than a fast and positive acting electromagnet. This is exactly the case and it is called a selector magnet. The selector magnet of the more common machines, such as Model 14 and 15, have two coils. The selector magnet of the Model 15 machine is shown in fig. 2.15 and the selector magnet of the Model 14 is shown in fig. 2.20.

The selector magnet in the receiver mechanism is actuated by the d.c. signal pulses received from a transmitting mechanism (of the same machine or any other machine). The armature of the selector magnet controls the selector mechanism which consists of a complex combination of various shaped levers, posts and springs. The On-Off pulses fed to the selector magnet are translated into mechanical pulses and fed to the lever system. In turn, there are five selector levers which determine the letter to be printed and these are positioned according to the coded pulse series.

This mechanism is driven through a clutch by the constantly running synchronous a.c. motor. The basic design of this unit is not the same as that of the transmitting unit. However, it is not considered sufficiently different to warrant a detailed description here as was given for the transmitting unit.

3

TELETYPE AND RADIO RECEPTION

IT WAS previously noted that the transmitting mechanism of the machine is not connected to the receiving mechanism of the same machine either electrically or mechanically. The transmitter and receiver circuit of the same machine can be connected together in a simple series circuit that includes a source of d.c. voltage. This is called a local loop and is shown schematically in fig. 3.1.

Selector Magnet Current

As pointed out earlier, some machines have two selector magnets and these magnets must be powered by a d.c. source. Since there are two coils the operator has the option of connecting them in series or parallel. In the series configuration the coils require a current of 20 ma and in parallel, 60 ma. This does not appear to be correct when looked at from the conventional Ohms Law standpoint.

This has puzzled more than a few beginners who are prone to think of the two coils in terms of their d.c. resistance. Actually, what we are really interested in is the pulling torque and action of the armature and its associated mechanism in each instance, so it works out that the required current for the coils connected in parallel is 60 ma instead of 40 ma as one might think.

The d.c. resistance of each selector magnet coil is relatively low. It is in the neighborhood of 100 ohms, give or take a few ohms, depending upon the machine. Sufficient voltage is used so that several thousand ohms of series resistance is required. See the circuit of fig. 3.1.

There are several reasons for this. This makes it possible to remove the coils from the circuit, such as with a closed circuit jack, without leaving the battery voltage directly across the keyboard transmitter contacts. It also makes it possible to insert the selector magnet coils into the circuit or remove them without appreciably affecting the current limiting action of the external circuit.

These are very good reasons but there is still one other that is far more important. If there was no series current limiting resistor the required voltage to put 20 to 60 milliamperes through the selector coils would be 3 to 4 volts. The selector magnet coils have both resistance and a varying inductance (as high as 2 henries) with the inductance at its highest value at the moment when the armature is against the pole

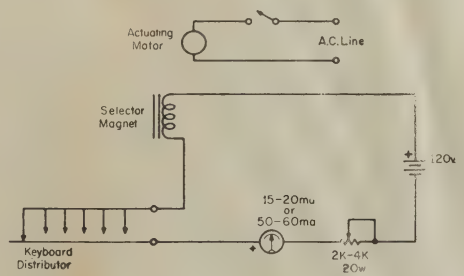


Fig. 3.1—Circuit above shows how the selector magnet (or magnets) are placed in series with the keyboard contacts, a source of voltage and a series resistance to form what is called a "local loop."

Fig. 3.2—The square wave in (A) is generated by opening and closing the switch in circuit (B).

piece. With a low voltage the time it takes for the current to build up to near 100% is too long and there is a mechanical lag in the operation of the relay. The time becomes much shorter as the voltage and resistance in the circuit is increased and these factors are no longer a problem.

A low voltage source such as 3 or 4 volts may be enough to operate the relay but not fast enough for printing. Let us suppose that the selector coils are connected in parallel which means that the current should be 60 ma. With a voltage of only 3 or 4 volts, the current through the coils will not come up to anywhere near the required 50 to 60 ma during the 22 ms pulse following a 22 ms space when the coil circuit was open. The coil current should reach 90% of its required value in no more than 1 ms after the distributor contact closes. The current through the selector coils should be as near to a square wave as possible. Figure 3.2(A) shows a perfect square wave produced by opening and closing the switch shown in fig. 3.2(B), a resistive circuit.

Whenever the opportunity presented itself, attention has been focused upon the fact that the teletype signal is made from 22 ms pulses, forming a square wave, produced by interrupting a d.c. voltage. In a circuit containing mostly inductance this square wave could not be generated. By placing the inductances in series with large values of resistance and using higher values of voltage the result is almost that shown in fig. 3.2(A).

Range Finder

An attempt should always be made to have the signal that your machine is required to copy as near a square wave as is possible. Although it is most desirable that the signal operating our printer be a square wave, it will ...tle fo... less and under certain circumstances ...nsider...bly much less and still give good copy.

As a matter of fact, the receiving mechanism is designed so that it requires only 20% of the 22 ms pulse or 4.4 ms of each selecting interval in which to perform its function. This is necessary in order to minimize errors in printing. This is particularly important in cases where transmission is over long h.f. paths such as encountered in the amateur bands. It is possible, under such conditions, for the transmitted pulses to be altered in time relationship to each other as well as becoming either lengthened, shortened or otherwise distorted. Only so much of this can be tolerated before the machine begins to print errors. The ideal arrangement would be for the 4.4 ms time, during which the selecting mechanism is performing its function, to fall in the center of the 22 ms interval. Teletype machines are provided with a "range finder" which is adjustable to accomplish this. The end result of this is shown graphically in fig. 3.3 for the letter Y. This may appear to be an ample amount of safety margin to insure perfect printing and it is—under normal conditions. However, this comfortable margin of safety can soon melt away under adverse receiving conditions. At this point, just about every trick in the book has to be resorted to in order to improve the copy.

Machine Circuits

Earlier it was made pretty plain that all characters, without fail, start with a 22 ms space and yet the pictorial view of the dots and spaces as shown back in fig. 1.2 indicates a very short pulse before the start of the 22 ms space for all characters. It will be recalled that the transmitter distributor stops at the end of each character and in the stopped position the sixth cam operated switch is left in a closed position. It stays closed until another character is sent, whether that be the next instant or minutes later. When the next character is to be sent, that closed contact must be opened. This happens almost instantly but not quite. Obviously, the next character starts at the end of the last. This is graphically shown in fig. 3.4 where the letters RST are put end to end.

The synchronous a.c. motor runs continually so long as the machine is in operation or so long as you are at the operating table and on the verge of putting it into operation. If you are not writing on the keyboard or receiving a signal on the receiving mechanism (printing)

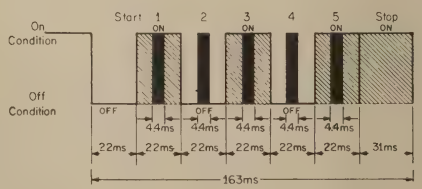


Fig. 3.3—The receiving mechanism is designed to function on a pulse whose duration may be as little as 4.4 ms out of the 22 ms time allowed. The rangefinder mechanism is used to place the received pulse in the center of the 22 ms interval as explained in the text.

the machine is silent except for the low drone of the a.c. motor. The silence is broken if the d.c. signal circuit (see fig. 3.5) is broken. The machine then runs open. As W4JTU once said, "You don't have much difficulty in telling when a machine is running open—it jiggles up and down like it's fixing to take off for the nearest fire exit."

Figure 3.1 shows the d.c. electrical circuit of a single Teletypewriter showing that the keyboard (actually the transmitter distributor contacts) and selector magnet are series connected with a d.c. power supply of 120 to 200 volts and a current limiting resistor. It is highly recommended that you first hook up your machine in this fashion in order to become thoroughly familiar with its operation. When you press a key the transmitter distributor begins to function. The On-Off operation of the transmitter distributor contacts causes the selector magnet mechanism and printing mechanism to faithfully follow by typing out what is being fed to the keyboard.

The circuit of fig. 3.1 can be extended to include two teletype machines that are connected together by a two wire line as shown in fig. 3.5. These may be on the same operating desk or they can be miles apart. It becomes apparent, from an inspection of this circuit, why it is desirable for the keyboards to be in a closed or On (*mark*) position. It can be seen from fig. 3.5 that the keyboard of machine #1 must be in the *mark* position if you are to send to #1 from the #2 machine and vice-versa.

Machine Connectors

There are three basic circuit connections to be made to a teletype machine requiring three sets of wires. First, there is the a.c. cord to the synchronous motor. This may go directly to a wall socket or it may be wired through another piece of ham shack equipment.

The keyboard and selector magnet should each be terminated in a plug. This makes it possible to unplug the machine so that it can be moved or worked on.

It is commercial practice to distinguish between these two circuits by color coding the selector magnet cord and plug red, and the keyboard cord and plug black. This makes it possible to know, at a glance, which is which,

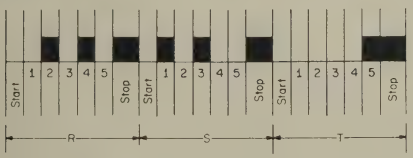


Fig. 3.4—The letters RST, when placed in sequence, present the pulse series shown above.

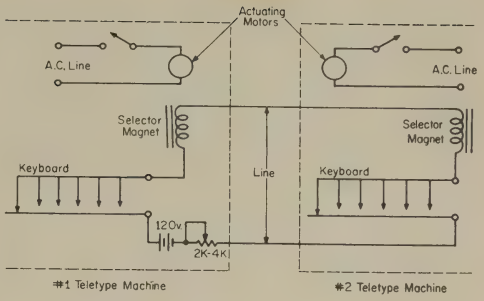


Fig. 3.5—The circuit of fig. 3.1 can be extended to include two machines, one of which may be miles away, for direct wire operation.

without having to trace the cord back into the machine.

The wiring found in the base of a machine will amaze you when you see it for the first time. One must remember that this wiring was put there because of the external or associated circuits required for the machine's original use. Many of those requirements necessitated extra switches, buttons, jacks, *etc.*, that were mounted on or near the machine or its supporting table. Some hams modify or replace this with wiring and circuits of their own that are every bit as complicated or even more so than the original. I prefer to keep the machine wiring simple and restricted to the three plug-in cords. This way, you do not have to take out the present machine wiring or do much to it to get the three lines properly connected.

I hope that by now that you have been convinced of two things: Electrically, the teletype machine could not be much simpler, as shown in figs. 3.1 and 3.5; and mechanically, it is not a monster but a marvel—something that will add many pleasant hours to your hamming enjoyment.

Radio Applications

The application of the teletype machine to radio does not alter or add anything to that which has been covered up to now so far as the machine itself is concerned. It's an On-Off d.c. operated machine and remains so when operated with radio equipment.

Any person that knows the Morse code is aware of what On-Off signals are. Anyone who has read to this point, knows that a teletypewriter is an On-Off signal operated machine and certainly any ham knows that c.w. telegraphy is an On-Off signal. Furthermore, the reception of c.w. telegraphy is simple and uncomplicated provided your ear can follow the speed of transmission and the signal is reasonably free of the multitudes of interference that can thwart reception. Linkage from the headphones or loudspeaker, through air, to your

ears is direct with no devices needed.

This brings us face to face with the first problem we encounter in the application of teletype machines to the reception of On-Off radio signals. The teletypewriter has no "ear" to pick up the signal coming from the loudspeaker even if it is sent in the teletype code instead of the Morse code. Neither can the audio output of the receiver be connected directly to the teletype machine selector coil. It will be remembered that it takes a d.c. voltage of 120 to 200 volts and a minimum d.c. current of 20 ma to properly operate the selector magnet and its mechanism.

The reception of either On-Off code can be the same up to the output transformer of the receiver. At this point, something more is required for the teletype machine operation. Alas, the mysterious black box enters! Actually, it is not all that bad, so let us review the problem.

We need to take the On-Off a.c. audio signals from the secondary of the receiver output transformer and eventually end up with On-Off d.c. signals that will have a circuit voltage of 120 to 200 volts d.c. and the required current of 20 or 60 milliamperes (operator has option as to which way he connects the selector coils —series or parallel) with which to operate the selector magnet.

It is almost certain that if left at this point, without further aid, most of you would solve this problem in due course. Place the selector magnet in the plate circuit of a power tube (usually two 6AQ5s in parallel), that meets the current and voltage requirements and properly couple from the output of the receiver to the grid of the power tube usually called a keyer tube. The whole circuit will be given in due course.

RTTY actually began in the ham bands as a make-and-break or On-Off keying of the radio transmitter (using the Teletype code, of course) just as had always been done with the Morse code. In the beginning, the c.w. boys were so opposed to the carrier staying on constantly (while transmitting) and using frequency shift keying, as is now done, that the FCC would only allow make-break-make keying. Make-break-make keying of the radio signal is satisfactory *only* so long as you get good copy on the receiving machine. It was soon discovered that On Off keying for radio teletype was highly vulnerable to signal fading, QRN, QRM, *etc.* Of course c.w. was vulnerable too but RTTY was more so. When you are copying a c.w. signal you can adjust the tuning or the b.f.o. slightly which may give the received signal an edge over QRM. This isn't necessarily so in copying On-Off RTTY.

The teletype machine may do fairly well with the On part of the signal. It is the Off part of the signal that gives the trouble. A study of the teletype code shows that the Off or spaces of no signals are just as important as the On signal parts. Take, for instance, the teletype code for the letter Y as shown in (b) fig. 3.6. If the "space" signal unit 2 is not received, the character now becomes the letter Q as shown in (a). If neither the unit 2 space or unit 4 space is received, the character is neither Y nor Q but *Letters* as shown in (c).

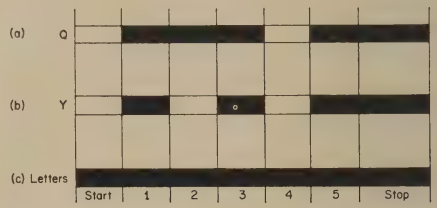


Fig. 3.6—Teletype code letters Q and Y and the "Letters" character that shifts the machine typing mechanism from FIGS to LTRS. If unit 2 of Y becomes a *mark* the character now becomes Q. If both units 2 and 4 of Y become a *mark* then the character becomes "Letters."

One thing is sure, the teletype machine is going to "read" every unit of the five unit code as something and that something has to be either *mark* or *space. The big problem is getting it to respond to the space units in the face of interference.* How many times have you been copying a c.w. station only to find when he stood by that one or more stations were underneath that were just about as loud? The slight difference in signal strength made it possible for you to copy. If a teletype machine is copying the letter *Y* and another strong signal is present during the *space* time for unit 2 then the machine copies unit 2 as *mark* causing copy error. The teletype machine may not only copy the *mark* signals from the station that you are trying to copy, but it may also copy any other strong pulses (as *marks*) from other stations that are present during intervals of *space* from the desired station. With considerable interference, the machine may act as though nothing but *mark* pulses are being sent or that the carrier is not being interrupted at all. It can be seen from this that On-Off RTTY cannot tolerate very much interference of any kind. No small wonder why the RTTY'ers began to clamor to the FCC to get the rules changed to provide for frequency shift keying of the transmitter for RTTY work in the ham bands. This the FCC did, making it effective in February 1953. They called it f.s.k., F1.

F.S.K.

The conclusion can now be reached that although the teletype machine operation depends just as much on spaces as it does on pulses of signals, the space is most difficult to transmit satisfactorily by radio with make-break-make signaling. It becomes obvious that some means must be devised whereby the space can be sent by radio by another pulse signal and then converted to a space at the receiver end. With this thought in mind, *frequency shift keying* came into being (f.s.k.). With this system, *energy is sent for each pulse.*

F.s.k. is often referred to as a dual or double On-Off system. If you used two transmitters and keyed one for mark and the other for space, then you would have a true double On-Off system. This is not necessary in actual practice. It is far more practical to use one transmitter and keep its carrier on during the entire transmission. Teletype keying is accomplished by shifting the transmitted r.f. carrier frequency a few hundred cycles from say frequency A to frequency B. The *mark* signal is transmitted on the A frequency and the *space* signal is transmitted on the B frequency. The transmitter frequency is instantly shifted from A to B and back, *etc.*, depending on the code units of the teletype character being transmitted. Frequency shift keying is accomplished at the v.f.o. (or crystal oscillator if such is used) of the transmitter. Vacuum tubes or solid state devices are both used in the frequency shift keying of transmitters. The actual make-break of a circuit of the transmitter is done directly by the teletypewriter keyboard transmitter contacts or indirectly through a relay. If a mechanical relay is used, then almost invariably a polar relay is used. Very few electronic relays are used for this purpose, although diode switching is used extensively. This will be covered shortly.

The keyboard transmitter contacts are operated either "dry" (with practically no voltage across the contacts) or "wet" (with normal voltage across the contacts). Both methods, dry or wet, are being used successfully. However, more care and maintenance is required to keep the keyboard transmitter contacts free of oil, carbon, dust or other foreign particles when there is no voltage at the contacts. A substantial voltage present at the contacts tends to keep them clean by means of the minute arcing that apparently burns much of the foreign material from the contacting surfaces.

A side or indirect benefit from frequency shift keying is that the plate power input does not turn on and off with the keying rate but stays constant since the power stays on so long as the transmitter is being keyed. The advantages of this are obvious—less TVI, less strain on the transmitter and not as susceptible to key-clicks as make-break-make keying.

The maximum frequency shift of 850 cycles for the amateur radio bands is established by F.C.C. rules and regulations for f.s.k. At first this was the only frequency (plus or minus 50 cycles) allowed. This is probably the most used frequency shift; however, many other shifts are now being used. At least considerable experimenting with other shifts goes on among the RTTY'ers. The other shifts are usually multiples of 170 cycles such as 680 cycles, 510 cycles, even down to 170 cycles. The main reason for the use of multiples of 170 cycles is convenience as well as giving some semblance of standardization. Commercial RTTY circuits using f.s.k. have shown that the smaller frequency shifts have an improved signal-to-noise ratio.

The "rest" or carrier frequency ("A" as earlier explained) before keying starts is considered the *mark* frequency such as 14,100.000 kc. It is customary to shift down in frequency for *space*. In this case a shift of 850 cycles down to point "B" would give a *space* frequency of 14,099.150 kc. Occasionally, an operator may frequency shift key his transmitter in such a way that the frequency shifts up for *space* instead of down. This is considered as sending "upside down." Under these conditions, at the receiving machine, the *mark* becomes *space* and *space* becomes *mark* and the machine, as can well be imagined, prints nothing but gibberish. Obviously, the greatest objection to sending "upside down" is the confusion it creates. The receiving operator may not be able to determine at first if he is trying to copy a poor signal or that the signal is just upside down.

All receiving setups have a "turn over" switch somewhere in the RTTY lineup for this very purpose. When in doubt, you flip the switch. Just the same, it is somewhat of a nuisance if many of the fellows slip into the sloppy operating habit of sending upside down.

Remember that the carrier is on at the key-down (*mark*) point "A" and also at the key-up (*space*) point "B". The question may arise as to why the rest frequency is not the key-up point B (space) if we are not actually keying the transmitter. It will be remembered in the discussion of teletype machines and the teletype code that there is a 31 ms rest pulse (*mark*) at the end of each character. The machine "rests" at this point until the next character is keyed. If the machine were to rest on space while we were thinking about what we were going to say next it would "run open" and make so much noise that we couldn't think. With c.w. telegraphy we are used to considering the key-down condition as existing only

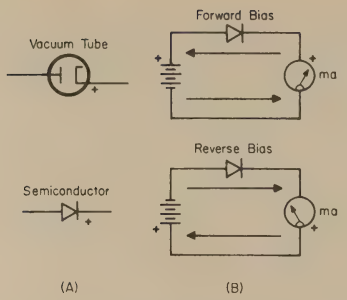


Fig. 3.7—(A) Comparison between the vacuum tube diode and semiconductor symbol. The terminal marked + on the semiconductor is the equivalent of the cathode. The arrow of the semiconductor symbol points *against* the direction of electron flow. (B) shows the heavy current flow when the diode is forward biased and the very slight current when the diode is reverse biased. Note carefully, the directions of current flow in each example. When reverse biased the leakage current flows in the opposite direction.

while we are sending since nothing is being sent when the key is up (carrier off). With f.s.k. we are sending a *space* signal that is just as strong as the *mark* signal. Since there is twice as much power in the f.s.k. system (double On-Off) its transmitted intelligence is considered to have a 3 db power gain over an On-Off system.

F.S.K. Circuits

Unfortunately, practically no transmitters make provisions for frequency shift keying, even the expensive ones. An exception to this was the Central Electronics 100V and 200V transmitters. They not only provided for f.s.k. but made the frequency shift variable by the simple turn of a knob on the front panel.

There is no standard f.s.k. circuit that is equally adaptable to all transmitters. The circuit will vary, depending upon the transmitter. Basically, most of the circuits depend upon the addition or removal, during the keying process, of a small value of capacitance or inductance in the v.f.o. or crystal oscillator circuit that will shift the transmitter frequency the required amount. Some of the circuits are very simple. In fact, none of the more common ones are too complicated or very difficult to add to most transmitters.

It is not within the scope of this text, nor practical, to give circuits for converting specific commercial transmitters to f.s.k. The basic circuitry is covered here so that the individual operator may choose the method best suited for his particular transmitter.

In the early days of RTTY, the 6AL5 (dual diode) tube was used extensively in the "diode switching" of f.s.k. circuits. However, with the rapid development of solid-state devices, the crystal diode has replaced the tube in most f.s.k. circuits. It is generally conceded that the average ham is familiar with the germanium diode or at least its action as a rectifier or detector. Fortunately, the practical application of the diode to "switching" in f.s.k. circuits is neither more complicated or involved than rectifier action.

The operation of the solid state or semiconductor diode is described in terms somewhat different than used in vacuum tube diodes. The vacuum tube and semiconductor diode symbols are shown in fig. 3.7 (A). When the diode is biased so as to conduct, as shown in fig. 3.7 (B), it is said to be *forward biased*. When biased with a polarity that prevents conduction it is said to be *reverse* biased.

In a vacuum tube, when the plate is made negative with respect to the cathode, so little current flows that for all practical purposes we can say that reverse current does not exist. However, in the solid state diode this is not so. Due to minority carriers, when the semiconductor diodes are reverse biased, a small current *does* flow. This reverse bias current is generally considered undesirable and is referred to as leakage current.

The basic circuit of f.s.k. by means of a diode is illustrated in fig. 3.8 (A). When switch S_1 is open there is no conduction through the circuit consisting of RFC_2 and R_1. The equiva-

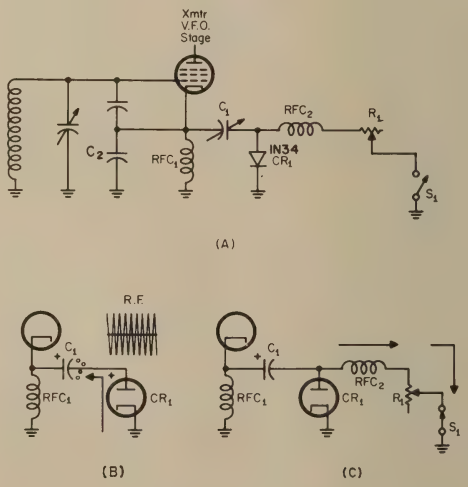


Fig. 3.8—(A) Basic frequency shift keying circuit with diode switching. (B)—Equivalent circuit when S_1 is open. Capacitor C_1 charges to the peak r.f. voltage and cuts off diode CR_1. (C)—When S_1 is closed C_1 can discharge and the diode CR_1 conducts longer effectively shunting C_1 across C_2. This lowers the oscillator frequency.

lent circuit is shown in (B). Some of the r.f. energy developed by the oscillator stage appears across RFC_1 and is coupled to the diode CR_1 through C_1. On the first positive half cycle CR_1 conducts and charges C_1 as shown in (B). Capacitor C_1 charges to the peak value of the r.f. signal and as the polarity indicates will prevent the diode from conducting further. Only when the charge on C_1 falls below peak r.f. will CR_1 conduct. The charge does eventually drop slightly due to leakage through the capacitor and diode and C_1 recharges on the positive half cycles. Because the diode is continually reversed biased at a value equal to the peak r.f., we may say that for all practical purposes it does not conduct and C_1 is not in the circuit across RFC_1 and RFC_2.

When switch S_1 *is* closed, the circuit is as shown in (C). Now the charge on C_1, caused by the conduction of CR_1 during the positive half of the r.f. cycle, can leak off through RFC_2, R_1 and S_1. How rapidly the charge leaks off is determined by the setting of R_1.

When the value of R_1 is very low the charge leaks off rapidly and CR_1 is able to conduct for a greater period on each positive half cycle. Thus C_1 is in the circuit, in parallel with C_2 and becomes a factor in determining the frequency of the oscillator. In other words, the diode conducts when the switch is closed and doesn't conduct when the switch is open. The setting of R_1 can control the amount the diode conducts and therefore how effectively capacitor C_1 is in parallel with RFC_1. Increasing the resistance of the pot R_1 decreases the frequency shift which is maximum when the pot resistance is zero.

This means that the frequency increases on *space* when the switch (keyboard contacts) is open. This is in reverse to what it should do, so the v.f.o. would be keyed upside down if your transmitter is of the v.f.o. buffer, amplifier type design. If, on the other hand, your transmitter is of the heterodyne type, the frequency shift could be in the right or wrong direction, depending upon your transmitter design.

Keying right side up with this circuit can be accomplished by replacing C_1 with a variable inductance of about 50 microhenries maximum depending upon the frequency of the v.f.o.

Reversing the diode polarity does not alter the operation as described, in any way, except to rectify on the other half of the r.f. cycle due to the self-rectifying action of the diode.

The function of RFC_2 in fig. 3.8 is to isolate the r.f. energy of the oscillator circuit from the lines running out to R_1 and S_1. Switch S_1 as you may realize now, is the keyboard contacts and the lines running to the contacts in the machine may be rather long. To prevent the capacity of the leads from affecting the oscillator we use RFC_2.

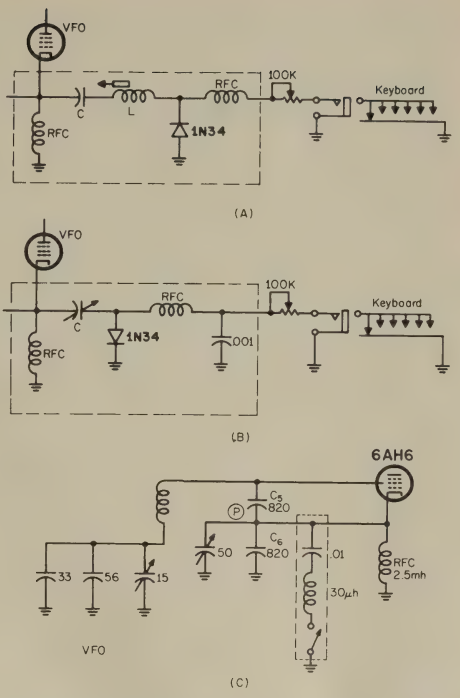


Fig. 3.9—Three typical frequency shift keying circuits for the v.f.o. using "dry keying" contacts. Circuit (A) uses an inductance to shift the frequency and (B) uses a capacitor. Circuit (C) is that of the author's v.f.o. showing the values for practical operation. This is further discussed in the text.

Dry Keying

Two typical methods that have been used to frequency shift key the v.f.o. of amateur transmitters are shown in fig. 3.9 (A) and (B). These systems, shown in fig. 3.9 do not apply voltage to the keyboard contacts and are thus called "dry." That portion of the circuit in the dotted line enclosure should be as close to the v.f.o. tube as possible. In addition, that portion of the circuit should be rigidly anchored and should be as well engineered as the v.f.o. circuit to which it is being added. The mounting of the potentiometer and jack is not critical and they can be located at any convenient place available on the transmitter.

It is certainly not the intent here to give an exact circuit including the values of all components that will work for any v.f.o. In the first place, there is the problem of keying the v.f.o. in such a way that one is keying right side up. If it is not possible to conveniently key your v.f.o. right side up, it may be simpler to use a relay to key with the keyboard contacts operating the relay (relay with s.p.d.t. contacts). Secondly, the circuitry for all vf.o.'s are not the

same and each must be considered separately. Normally, the value of C should be less than 50 mmf for the circuit shown in fig 3.9 (B) and about 0.01 mf for fig. 3.9 (A) and L should be less than 50 uh. However, these values can vary over considerable limits, dependent upon the v.f.o. circuit as well as the operating frequency.

The 1N34 acts as a diode switch in both circuits (A) and (B) of fig. 3.9. Consider that in fig. 3.9 (A) C is fairly large (in the order of 0.01 mf) and acts as a coupling capacitor and that inductance L is sufficiently large enough to shift the v.f.o. frequency the required maximum that may be used. The shift is controlled by the 100K potentiometer which should be adjusted in the *mark* condition which is with the keyboard circuit closed. The maximum shift occurs when the pot is at zero resistance. If the required shift at this point is not enough, then the slug-tuned inductance L should be increased.

When the keyboard is in the *mark* (closed position) a path to ground is provided for the d.c. current resulting from rectification of the r.f. by the diode. This conduction in the 1N34 diode likewise provides for a low resistance and direct path to ground for the r.f. circuit through inductance L. Thus, inductance L becomes a contributing factor in the overall v.f.o. circuit frequency. Adding L naturally causes an upward shift in the frequency of the v.f.o. (increase).

This can best be shown by again referring to the author's own v.f.o. modification shown in the dotted enclosure.[5] Note that the basic f.s.k. modification is shown as a 0.01 mf capacitor, a 30 uh inductance, and a switch, all in series from cathode to ground. Obviously, if the 30 uh inductance were not in the circuit, closing the switch would place the 0.01 mf capacitor across the 850 mmf capacitor C_6, which would lower the frequency of the v.f.o. Now, mentally break the circuit and insert the 30uh inductance as shown. It is a well known fact that inductive reactance is determined from the formula $X_L = 2\pi FL$ and capacitive reactance is determined from the formula, $X_C = \frac{1}{2\pi FC}$.

From these formulas one may quickly determine the respective reactances at the v.f.o. operating frequency (5100-5700 kc). The reactance, X_L, is in the neighborhood of 1000 ohms 1962 ohms at 5.1 mc and 1076 ohms at

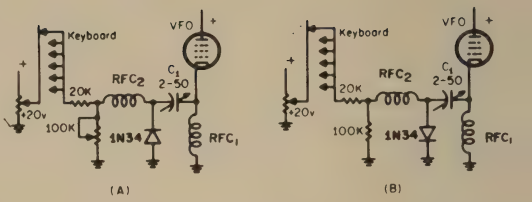


Fig. 3.10—Two circuits illustrating "wet contact" keying of the v.f.o. Circuit (A) has a potentiometer to adjust the frequency shift while (B) does not. The shift in (B) is adjusted by setting the 2-50 mmf capacitor.

5.7 mc) and X_C is in the neighborhood of 3 ohms, with the exact value of each depending upon the frequency setting of the v.f.o. dial. The voltage vectors of X_L and Xc are at 180 electrical degrees phase relationship with each other, acting in opposition. In this instance the net reactance would be X_L—X_C, inductive.

When the switch is closed (in the dotted enclosure of fig. 3.9 (C)) the inductive reactance discussed above is placed directly across capacitor C_6. The vector current of the net reactance (X_L) is in 180° phase relationship with the vector current of capacitor C_6. The resultant current would be the algebraic sum of the two, thus being less than either of the two and the impedance, Z, from point P to ground (across C_6) would be increased.[6] This produces the same effect that reducing the value of C_6 would have, which means that the frequency would be increased.

Wet Contacts

Another f.s.k. method is one called the "controlled voltage" system or "wet contacts" and is illustrated in fig. 3.10 (A) and (B). In fig. 3.10 (A) the diode is not biased by self-rectification but is blocked by the application of plus 20 volts to the cathode terminal when the keyboard is closed (*mark*) When the keyboard opens (*space*), the diode is unblocked, rectifies r.f., charges C_1 which then discharges through the RFC_2, and the 100K pot. This permits the diode to conduct and places C_1 in the oscillator circuit to lower the frequency in the *space* position.

If it is desired to raise the frequency during the *space* period, an inductance can be substituted for C_1 as discussed previously or the circuit of fig. 3.10 (B) may be used. Note that the diode is reversed in this circuit and there is no shift potentiometer. The shift is controlled by the 2-50 mmf capacitor and it must be positioned in such a manner in the v.f.o. compartment that it is accessible. The plus 20 volts is applied to the plate of the diode on the *mark*. The diode conducts and places the 2-50 mmf

[5]Tucker, D. J., Copeland, J. L., "A Single Sideband Exciter," *CQ*, February, 1962, page 54.

[6]Tucker, D. J., *Introduction To Practical Radio*, (New York: The MacMillan Co.) pages 218 to 270.

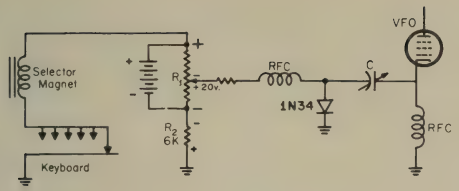


Fig. 3.11—The above circuit biases the diode with a fixed voltage in either the forward or reverse direction. The operation of the circuit is given in the text.

in the oscillator circuit. The *space* removes the plus voltage from the diode plate and the capacitor C_1 charges on the r.f. half cycles cutting the diode off as previously explained.

The circuit shown in fig. 3.11 is completely voltage controlled and provides both the forward and reverse bias. The power supply voltage is impressed across R_1. When the keyboard contacts are open (*space*) the drop across the lower portion of R_1 is the only voltage applied to the diode plate. The diode conducts and the shift capacitor C is in the circuit.

For *mark*, the keyboard contacts close and a current flows through R_2. The value for R_2 *is chosen so that* it provides a drop in excess of 20 volts. As the polarities show, the drop across R_2 cancels the drop across the lower part of R_1 and the diode is now reverse biased; C is now out of the circuit. The resistor on series with the *RFC* limits the diode current.

It should be realized that it is almost impossible to add the f.s.k. circuit of fig. 3.8 or any of the other circuits for that matter, to a v.f.o. without experiencing a slight frequency shift because of the capacitive effect of the added circuit as well as the very small leakage current of the diode in the reverse direction as mentioned earlier. The calibration of the v.f.o. shouldn't be appreciably affected if the parts and associated wiring are carefully wired and placed.

Two Tone Signal Reception

C.w. telegraphy is a single tone transmission. The reception of c.w. through the use of a beat frequency oscillator is something that the amateur has been familiar with for a very long time. The operator is able to produce a low frequency beat note when the b.f.o. is placed near the carrier or a shrill high pitch beat note when the b.f.o. is tuned some distance from the carrier. This is illustrated in fig. 3.12. Usually, the operator adjusts the b.f.o. so that the beat note is most pleasing or easiest to copy.

The same approach is used to copy an f.s.k. signal with the amateur receiver except that

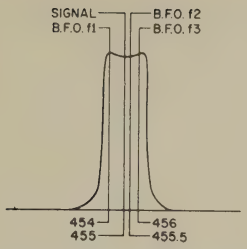


Fig. 3.12—The curve above illustrates b.f.o. action. The received signal is at 455 kc. When the b.f.o.. is at f_1 (low side) or f_3 (high side) a beat note of one kc will be heard. If the b.f.o. is set at f_2, a 500 cycle note will be heard for the same input signal.

now two carriers beat against the b.f.o. in the i.f. circuit. Also, it now makes a difference if the b.f.o. is on the high side or the low side Figure 3.13 (A) and (B) show the *mark* and *space* signals properly located in the receiver i.f. bandpass. Figure 3.13 (A) shows the audio frequencies developed when the b.f.o. is on the high side of the i.f. bandpass.

When frequency shift keying a transmitter, the *mark* signal is the higher frequency and the *space* signal the *lower* frequency. When receiving the signals the b.f.o. is set to convert the mark signal to 2125 cycles and the space signal to 2975 cycles. (This is for an 850 cycle

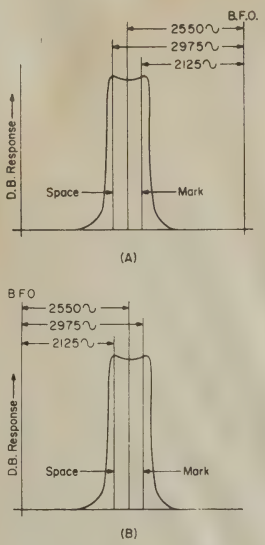


Fig. 3.13—I.f. bandpass of the receiver in (A) shows the b.f.o. located on the high side. The space and mark signals are properly located to produce the correct audio tones. In (B) the b.f.o. is located on the low side of the i.f. and with the same mark and space signals the wrong audio tones are produced.

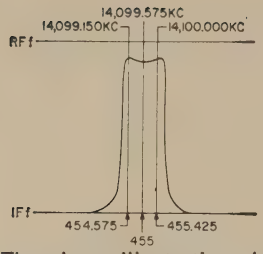


Fig. 3.14—The above illustration shows how the mark and space signals are converted to i.f. signals of specific frequencies as explained in the text.

shift at the transmitter.) Why these frequencies are used will be explained in a few moments. Now notice that with the b.f.o. on the high side as in fig. 3.13 (A) we accomplish this. Figure 3.13(B) shows how the same *mark* and *space* signals produce reversed audio tones when the b.f.o. is shifted to the low side of the i.f. bandpass. Why shift it then? Actually it isn't shifted to the low side unless the *mark* and *space* signals are reversed. How do they get reversed? This could happen at the transmitter as explained previously. A careless operator could transmit the *mark* signals as the lower frequency and the *space* as the higher frequency. When receiving this transmission, setting the b.f.o. on the low side would correct the audio tones and produce 2125 cycles for *mark* and 2975 cycles for space.

The problem of low or high side settings becomes even more involved and no exact standard can be set. We cannot say, "Always set your b.f.o. to the high side to receive normal RTTY transmission." It simply wouldn't be so because the design of the receiver itself is involved.

Let's review the action of a superheterodyne converter stage. In order to convert an r.f. signal to the i.f. frequency the oscillator must be either 455 kc below or above the r.f. signal. Either oscillator frequency will do the job. In some receivers the oscillator works below the incoming signal, in others above the incoming signal and in still others above on some bands and below on others. Let's see what difference it makes. Consider first the receiver with the oscillator working below the incoming signal. The center frequency of the r.f. signal is 14,099.575 kc and to produce a 455 kc signal the oscillator is 14,099.575 —455 kc or 13644.575 kc. This is shown in fig. 3.14. Now when the transmitter is keyed it will rise 425 cycles on the *mark* and drop 425 cycles on the *space* signal. The *mark* frequency is 14,100.000 and is converted to 14100.000 kc —13644.575 kc or 455.425 kc. The space signal will be 14,099.150 kc and when converted will appear as shown in fig. 3.14.

This is all normal; but what happens when the receiver oscillator works *above* the r.f. signal? The *mark and space* signal reverse positions and the copy is flipped. The b.f.o. must now be moved to the low side for correct copy.

Stop to think, for a moment, what the effects are in double and triple superhets where some oscillators are above and others below the signal frequencies.

All of the above may seem a bit complicated and far-fetched to the beginner. Actually you don't need to literally take your receiver apart to see if it "zigs or zags" or if it zig-zags and then zags. With a little practice in tuning in RTTY signals, you will soon find out whether you need to set the b.f.o. of your particular receiver on the high side or the low side for the reception of RTTY signals that are in turn properly sent (right side up) in the first place. Then there is the terminal unit or converter (the mysterious "black box" yet to be covered) which has a *reversal switch* which further simplifies this whole subject. When in doubt, throw the switch.

Audio Frequencies

I am sure that you are wondering as to why the b.f.o. is set so that the two beat notes received are 2125 cycles (*mark*) and 2975 cycles (*space*). The b.f.o. can be set at some other point producing two tones such as 1275 cycles and 2125 cycles or for that matter, 1000 cycles and 1850 cycles. The 2125 cycle and 2975 cycle frequencies were chosen because they were standard with the wire services for many years. Most of the converters in use in the ham bands are designed for these two audio frequencies. Much experimenting is presently being carried on with other frequencies. In fact, other shifts are used which naturally means other frequencies. If a shift of 425 cycles was used, *mark* and *space* would now be 425 cycles apart such as 1275 cycles (*mark*) and 1725 cycles (*space*).

Receiver Bandpass

It should be noted that the positioning of the *mark* and *space* signals in the pass-band of a receiver i.f. can have a lot to do with the reception of the two signals. The correct positioning of the two frequencies, regardless of what they might be, is shown in figs. 3.12, 3.13 and 3.14. The two frequencies, regardless of what they are, should *straddle the center of the passband*. With a very sharp passband to be found in so many of our receivers these days, this is very important. It wouldn't take a lot of misadjustment of the b.f.o. to slide one or the other of the two frequencies clear out of the i.f. passband and you would have the equiva-

lent of an On-Off system with just one tone supplying the information.

One should not only be familiar with the bandpass capabilities of his receiver but have a full understanding of the relationship between the receiver i.f. bandpass, the two f.s.k. frequencies, and the b.f.o. frequency. One should know the exact setting for his b.f.o. to position the f.s.k. signals such that they straddle the center of the i.f. passband as has already been pointed out. If one is not sure of the correct setting of his receiver b.f.o. for this, then he should determine this before he seriously tries to copy RTTY. One way to do this is to transmit the *mark* and *space* frequencies alternately from your own transmitter v.f.o. and tune your receiver so that the response is equal for the two frequencies. Naturally, this should be done with the receiver b.f.o. off and watching the S-meter while you are tuning the input of the receiver. If you tune either frequency for maximum S-meter reading, then the other one will read lower on the S-meter. This is because you have the one with the highest S-meter reading in or near the center of the i.f. passband of your receiver and obviously the other frequency is to one side or the other. The object is to tune each such that they straddle the center of the receiver i.f. passband. With this condition the S-meter reading should be the same for each. When this is done the b.f.o. should be turned on and adjusted to 2550 cycles so that the beat note from *mark* is 2125 cycles and the beat note from *space* is 2975 cycles. (Assuming the shift to be 850 cycles). Be sure that the previously adjusted tuning for the equal reception of the two signals *is not touched* while this adjustment of the b.f.o. is being made. *The b.f.o. should be left at this position* so long as the signals being received uses the 850 cycle shift or any other shift whose beat notes you wish centered on 2550 cycles. The machine is on *mark* when resting so this suffices for the transmission of a constant *mark* signal. A constant *space* signal can be transmitted by simply breaking the keyer circuit. The easiest way to do this is to open the break switch on the machine.

Receivers For RTTY

Space does not permit the discussion of all the merits of various receivers for use in copying RTTY signals. However, we should call attention to a few salient points if one happens to be in the market for a new receiver at this time and wishes to use it for RTTY work. Also, the discussion of the pros and cons of receivers for RTTY work may enable you to appraise your present receiver for use in RTTY work. There are a number of receivers on the maket that are capable of doing a good job. There are a number of others that will do an acceptable job, although their performance may leave something to be desired. Then there are, of course, others whose performance leaves one with a rather frustrated feeling. A ham with s.s.b. experience has learned to appreciate a stable receiver with little frequency drift. One hardly gets started in RTTY before he discovers that receiver stability and low frequency drift is even more desirable for RTTY work than it was for s.s.b. work. Stability, then, should perhaps be the first consideration, as it is quite annoying to have the receiver drifting off the RTTY signal being received. Reception of an 850 cycle shift signal requires a fairly stable receiver. With a 170 cycle shift, *very* little drift can be tolerated.

Selectivity should perhaps be the next consideration. Generally, a receiver designed especially for a.m. usually has a broad bandwidth, possibly 5 or 6 kc. It is desirable to have a much narrower bandwidth for RTTY work, depending upon the shift. Certainly a bandwidth of 2.1 kc or even 3.1 kc is to be desired, instead of the 5 or 6 kc bandwidth invariably found in the older receivers.

Another desirable feature for RTTY work is a product detector, to be found in the latest receivers with provisions for the reception of s.s.b. signals. Such receivers are also usually supplied with 2-3 kc bandwidth filters with fairly steep sides. Receivers equipped with product detectors have a number of advantages, such as being able to use a.g.c. while receiving c.w., which certainly helps in receiving RTTY signals in the presence (and when isn't it present) of fading, particularly severe fading. Don't forget to consult your receiver instruction manual for information on the operation of your b.f.o. and other features of your particular receiver. For instance the Collins 75S-3 has a special section (2.5) on RTTY tuning. In fact, the b.f.o. has a calibration dot near the —1 point on the b.f.o. calibration scale for RTTY copying. It also has a calibration dot near the +4 point on the b.f.o. calibration scale that reverses the *mark* and *space* signals. This is for copying "upside down" signals.

Audio Image Interference

One other word of caution before you desert the 850 cycle shift for narrow shifts. Be sure that the passband of your receiver i.f. is sufficiently steep and narrow also or else you will have problems of audio image interference. A receiver with a broad bandwidth can give you trouble in trying to copy narrow shift. Unless the image is 20 db or more down from the desired signal it may interfere severely. Figure 3.15 shows how interference may be caused by a signal, or signals, approximately the same

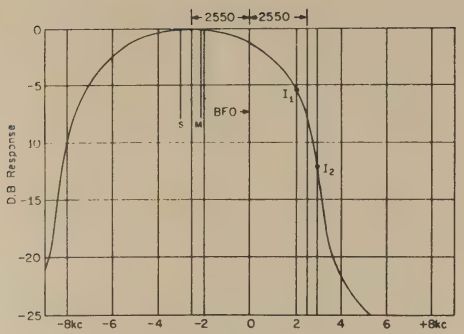


Fig. 3.15—Broad bandwidth in a receiver as shown in this selectivity curve makes the receiver susceptible to audio image frequencies (I_1 and I_2) which can interfere with the audio tones of *mark* and *space*.

frequency removed from the b.f.o. on one side as the desired *mark* and *space* signals are on the opposite side of the b.f.o. frequency. In fact, it is possible for the interfering audio signal generated on one side of the b.f.o. to have the same frequency as, say, the *mark* frequency produced on the opposite side of the b.f.o. This doesn't mean, however, that they *must* be the same for audio image interference to exist. An inspection of fig. 3.15 indicates that the receiver i.f. in question will amplify the desired *mark* and *space* frequencies more than the interfering signals by a few db's. However, in practice the interfering signals may be strong and the desired signals may be weak, which further complicates the problem. It can be seen from this last problem posed, that, under these conditions, a receiver with a selectivity curve much improved over the one illustrated in fig. 3.15 can still encounter trouble in the form of audio image interference.

A.F.S.K.

We come now to the "last frontier" in the process of frequency keying our transmitter for RTTY work. That last frontier is the frequency shift key of a transmitter by means of two audio tones modulating a transmitter carrier; it is called audio frequency shift keying or a.f.s.k.

Frequency shift keying that creates only two carrier frequencies is the only type of frequency shift allowable on the low frequency amateur bands. A.f.s.k. as well as f.s.k. is allowable on v.h.f. However, a.f.s.k. is used mostly on the 6 and 2 meter bands. Either a.m. (A2) or f.m. (F2) is permissible, with the highest allowable fundamental modulating audio frequency being 3000 cycles. A.f.s.k. is accomplished by alternately modulating the transmitter with the two audio tones of 2125(*mark*) and 2975(space). This is done by frequency shifting an audio oscillator and feeding its output into the transmitter's audio system where the two tones alternately modulate the transmitter. It can be seen that this creates a transmitter signal that has a carrier, two upper sideband frequencies and two lower sideband frequencies. The operator only has to tune in the modulated carrier, with his receiver b.f.o. turned off, to receive the two audio tones. If a.f.s.k. is applied to an s.s.b. transmitter, only a single sideband is transmitted but it consists of two alternate r.f. signals whose frequencies differ by the amount of the audio shift used in the a.f.s.k. which would be 850 cycles for an audio *mark* frequency of 2125 cycles and an audio *space* frequency of 2975 cycles.

Let us suppose that the carrier of an s.s.b. transmitter was set to a frequency of 14,097.025 kc, and then nulled out. The transmitter is set to transmit on the upper sideband. Next, the transmitter is modulated with the *mark* audio frequency of 2125 cycles which creates an r.f. upper sideband frequency of 14,097.025 kc plus 2.125 kc or 14,099.150 kc. Now the transmitter is modulated with the *space* audio frequency of 2975 cycles which creates an r.f. upper sideband frequency of 14,097.025 kc plus 2.975 kc or 14,100.000 kc. It is seen that in the a.f.s.k. keying of the transmitter that the *low* frequency r.f. signal (14,099.150 kc) is the *mark* signal. This is in reverse to our previous discussions wherein the *high* frequency r.f. signal (14,100.000 kc) is the *mark signal* for the f.s.k. keying of a transmitter.

Let us now suppose that the carrier of the same s.s.b. transmitter was set to a frequency of 14,102.125 kc and nulled out. The transmitter is now set to transmit on the *lower* sideband. Again, the transmitter is modulated with the *mark* audio frequency of 2125 cycles which creates an r.f. lower sideband frequency of 14,102.125 kc less 2.125 kc or 14,100.000 kc. Now the transmitter is modulated with the *space* audio frequency of 2975 cycles which creates an r.f. lower sideband frequency of 14,102.125 kc less 2.975 kc or 14,099.150 kc. In this case it will be seen that in the a.f.s.k. keying of the transmitter that the *high frequency* r.f. signal (14,100.000 kc) is the *mark* signal. It can be seen that this is now the same as for the f.s.k. keying of a transmitter as discussed in detail previously.

The end result of audio frequency shift keying an s.s.b. transmitter is the same as frequency shift keying of the v.f.o. of a c.w. transmitter in that it produces two keyed r.f. signals. This is the theoretical picture. In practice, it usually is not this good. In the first place, the two modulating audio tones must be pure sine waves which they probably will not be. Besides, there is the problem of the removal

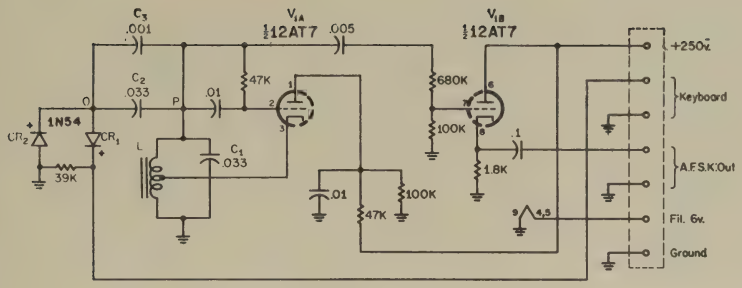


Fig. 3.16—Circuit of the "Twin City T.U." A.F.S.K. oscillator. The mark frequency is 2125 c.p.s. and the space is 2975 c.p.s.

of the carrier and unwanted sideband (on the other side) in order for the transmission to be truly classified as F1 instead of A2. A2 is not legal in the low frequency amateur bands. If one is prone to go ahead and a.f.s.k. an s.s.b. transmitter by modulating the transmitter in one of the sideband positions he should be very sure that the two carrier frequencies thus created do qualify under the F1 classification instead of A2. Remember, the low frequency bands only authorize F1 f.s.k. operation.

A.F.S.K. Circuits

As might well be imagined, diode switching is also used for audio frequency shift keying of an audio oscillator. Here again solid-state diodes are used. However, the diode switching circuits usually used for a.f.s.k. are slightly different from those f.s.k. diode switching circuits previously covered.

An a.f.s.k. oscillator is a relatively simple device. It is also easy to build and adjust. All of its components, except possibly the inductor required to resonate the oscillator to the two audio tones (*mark*—2125 cycles and *space*—2975 cycles), should be familiar to any ham. Figures 3.16 and 3.17 show two such oscillators. Both oscillators have been around for some time; fig. 3.16 shows the Twin City TU[7] oscillator and fig. 3.17 shows the W2JTP a.f.s.k. oscillator[8]. The inductor L in fig. 3.16 has an inductance of 88 millihenries and is tapped at midpoint. Originally an 88 mhy toroid telephone loading coil was used. Eighty eight mhy toroid coils are fairly common in RTTY circles. However, one with a center tap may not be as easy to find. The inductor L_1 in fig. 3.17 has an inductance of 250 millihenries.

[7] *CQ RTTY Handbook*, page 116.
[8] RTTY Column, Byron Kretzman, W2JTP. *CQ*, Jan., 1961, page 94.

Adjustments

Remember that with a.f.s.k. the high frequency, 2975 cycles, *space, is* obtained with the keyboard contacts *open*. The frequency of either oscillator should be first adjusted to the 2975 cycle frequency. Then the keyboard contact is closed (*mark*) and the oscillator is then adjusted to a frequency of 2125 cycles. Specifically, inductance L (88 mhy.) and capacitance C_1 (0.033 mf), with keyboard contacts open should resonate the oscillator of fig. 3.16 to the *space* frequency of 2975 cycles. Chances are that you will not hit the frequency right on the nose, as stock capacitors are not exact; nor are inductors, for that matter. The simplest thing to do, if you have a supply of the 0.033 mf capacitors, is to keep trying them one by one. If the oscillator frequency is on the high side, then more capacitance is needed. In this case, you may start with a capacitor, C_1, with a value lower than 0.033 mf, adding a padder of very low value if necessary. Otherwise, you have the other choice of removing a few turns at a time from one end of the inductor until the circuit resonates at 2975 cycles. Don't be too ambitious and take off too many turns at a time—remember that it is easier to take off than it is to put back on. Closing the keyboard circuit simply adds capacitors C_2 (0.033 mf) and C_3 (0.001 mf) across the coil L along with whatever value you ended up with at C_1. The chances are good that the oscillator will not be on 2125 cycles. Do *not touch* L or C_1. Do all of your substituting or adding at C_2 and C_3, otherwise, you will change your *space* frequency of 2975 cycles that you had just set.

The first half of the 12AT7 tube constitutes the oscillator and the second half of the 12AT7 tube is simply an audio amplifier. With the keyboard contacts open, an a.c. voltage, from the audio oscillator, (across L and C_1, to ground) is applied to CR_1 *and* CR_2 through

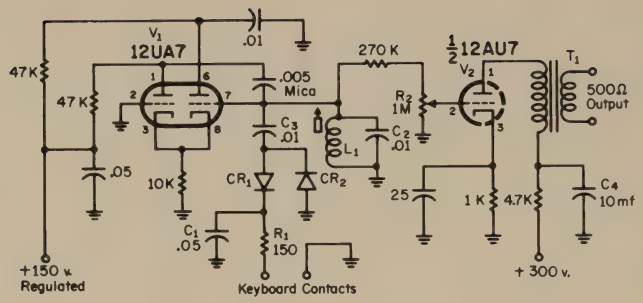


Fig. 3.17—Circuit of the W2JTP a.f.s.k. oscillator discussed in the text. Capacitor C_1 should be a disc ceramic. Diodes CR_1 and CR_2 are 1N34; T_1 is a Stancor A-3250.

capacitors C_2 and C_3. A pulsating d.c. voltage tends to develop across diode CR_2 because of its high back resistance and low forward resistance. Under these conditions, capacitors C_2 and C_3 tend to charge up to approximately the peak value of the a.c. voltage from point *P* to ground. Under the above conditions, there would be a measureable (with a good vacuum tube voltmeter) d.c. voltage across CR_2 to ground with the minus polarity at the ground side and plus at point *O*. This gives sufficient reverse bias voltage to diode CR_2 so that it will not conduct.

What about CR_1? Its polarity in the circuit is opposite to that of CR_2, therefore, it tends to build up a negative d.c. voltage from point *O* to ground. However, this is considerably nullified or restricted by the 39K resistor in series with CR_1 to ground. The result is that the positive voltage from point *O* to ground from the action of CR_2 is considerably greater than the negative voltage from the same point to ground from the action of CR_1. The algebraic sum of these voltages from point *O* to ground is positive. The net positive voltage from *O* to ground would tend for conduction through CR_1 except for the limiting effect of the 39K resistor in series with CR_1 to ground.

When the keyboard contacts are closed the 39K resistor is shorted, connecting the bottom end of CR_1 directly to ground. This gives a low resistance d.c. circuit through both CR_1 and CR_2. The net result is that capacitors C_2 and C_3 are effectively connected to ground in parallel with C_1 across inductor *L, thereby lowering* the frequency of the audio oscillator from the *space* frequency of 2975 cycles to the *mark* frequency of 2125 cycles.

The oscillator circuit shown in fig. 3.17 should be adjusted using the same procedure as outlined for fig. 3.16. Inductor L_1 and capacitor C_2 *of* fig 3.17 should be resonated to a frequency of 2975 with the keyboard circuit open. When the keyboard circuit is closed only the value of capacitor C_3 *should* be juggled in order to get the oscillator on the correct frequency of 2125 cycles for *mark*. All of the first 12AU7 is used in connection with the oscillator circuit and one-half of a second 12AU7 is used as an audio amplifier. The capacitors C_1, C_2, and C_3 of both circuits should be of the mylar or mica dielectric instead of ordinary paper insulated types.

Note that the diode switching circuits and the method of shifting or changing the frequency of the audio oscillation in figs. 3.16 and 3.17 are essentially the same. However, there are a few minor differences. For instance CR_1 in fig. 3.16 is connected to ground through a 39K resistor, whereas CR_1 in fig. 3.17 has an open d.c. circuit to ground with the keyboard contacts open. With this exception, the operation of CR_1 and CR_2 in fig. 3.17 is essentially the same as the detailed description given for fig. 3.16. Naturally, with the keyboard contacts open, diode CR_1 does not figure in the circuit at all, since it has an open circuit to ground and neither does CR_2 conduct, because of the reverse or back bias that builds up across CR_2 as already explained.

If one desires, a transformer may be used in the plate circuit of V_{1B} *of* fig. 3.16 to obtain an output from this audio amplifier, as was done in fig. 3.17, instead of taking the output from the cathode circuit. It may be found that there may be as much as 3 db difference in level between the two tones. This shouldn't give you too much trouble. However, you may equalize the two tones by placing an inductor, capacitor and resistor in series across the oscillator output. The value of inductor coil and capacitor selected should be such that they will resonate at the frequency that you wish to attenuate. The resistor is to control the amount of attenuation and its value should be determined experimentally.

4

CONVERTER (TERMINAL UNIT) BASICS

THE terms Converter or Terminal Unit (TU) as used in RTTY, mean the same thing. The commercial services probably stick to the name Terminal Unit more so than amateurs do. However, the amateur uses the name interchangeably, so I will do likewise. This is the mysterious black box briefly touched upon earlier. The purpose of the unit is to take the two RTTY tones from the output of the receiver and not only convert them into d.c. pulses but do it in such a way that perfect copy or as near perfect copy as is possible is obtained.

One finds various frequency shifts being used on the air, some wide, some narrow and many of them, regardless of the shift being used, operating off the desired frequency or frequencies that they are supposed to be on. Some operators only use RTTY on the high frequency or v.h.f bands for local or semi-local communications, while others only operate on the 14, 7 or 3.5 mc band or bands where selective fading, QRM and QRN is rampant. You may wonder why these seemingly irrelevant facts are mentioned at this time. Actually, facts such as these alter the requirements of a converter. For instance, a particular converter design may give an outstanding performance in the v.h.f. bands while on the twenty meter band its performance may leave much to be desired.

From the above, one wonders if there is any one converter that will serve all needs. Let us suppose, for instance, that one has been fortunate enough in obtaining a very good set of filters of the commercial variety for say 2125 cycles and 2975 cycles to use in building a converter. Some commercial filters of this type have extremely steep skirts and are very sharp indeed. The converter is built with great anticipation, using these filters. Finally the converter is finished and the operator breathlessly turns it on. Imagine his disappointment when he discovers that many of the signals are so far off from the 850 cycle shift that he can not get both the *mark* and *space* signal through his converter at the same time. He adjusts his receiver so that the *mark* signal is squarely in the middle of the passband of the 2125 cycles filter. Now he finds that the *space* signal misses the passband of the 2975 cycle filter altogether or else it is so far out on the edge of the passband that it is highly attenuated and hardly usable. If he adjusts his receiver so that the *space* signal is squarely in the middle of the passband of the 2975 cycle filter then he finds that the above is true for the *mark* frequency of 2125 cycles.

From this example, the beginner may be quick to assume that it is best to use broad filters and to avoid the use of sharp filters. That would not be a lasting solution to the problem at all but would only lead to other problems far more serious. This does not in

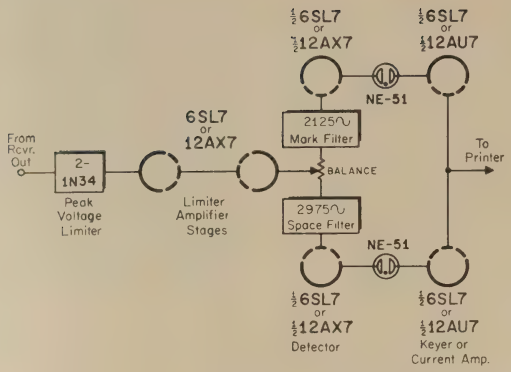


Fig. 4.1—Block diagram of the W2PAT Converter described in the text.

any way close the subject of filters, as we will have much to say on this subject later.

Converter Types

Up to this point, all discussions related to the converter have been associated with the audio tone type of converter. There are actually two general types. The other one, which has not been mentioned up to now, is an r.f. type that takes the RTTY signals at the i.f. section of the receiver instead of at the audio output. The r.f. type is usually more complicated and difficult to build. Besides it requires that some modification of your receiver be made in order to get the signals from the receiver i.f. section to the terminal unit. As a general rule, limiting, amplifying and detection is done at some radio frequency such as 50 kc and the latter stages of both types of converters are similar, if not identical.[9] The r.f. type will not be discussed further here since perhaps not one RTTY'er in twenty-five uses this type of converter.

Converter Purposes

The most important and basic reason for the converter is that it takes the two a.c. tone pulses and converts them into a pulsing d.c. current to operate the selector magnet of a teletype machine printer. Without this most fundamental function, all of the other reasons for the converter would be meaningless. A further purpose of the converter is to do those things that the receiver cannot do such as separate the two a.c. tones (mark and *space*). In addition, the converter, depending upon its design, may limit, amplify, or even supply a.g.c. to the two tone pulses. It detects the two signals and it may even change the time and/or amplitude relationship between the two a.c. tone signals, unintentionally or on purpose, to improve copy.

W2PAT Converter

The W2PAT converter was about the first real popular basic design in converters and was by far the most popular unit of its day or any other day, for that matter.[10] Now, many years later, one still finds a number of these units around, or various versions of it. The circuit diagram has been reproduced in the *ARRL Handbook* for many years. A block diagram of this unit is shown in fig. 4.1. The unit begins with two 1N34 diodes hooked in opposite polarity across the first half of a dual triode 6SL7 (now shown as a 12AX7 in the current *ARRL Handbook*). This dual triode forms two limiter-amplifier stages. The *mark* and *space* signals are split at this point by the *mark* and *space* filters and each signal is fed to its respective detector (½ of a 6SL7 or 12AX7 dual triode tube). Each detected signal controls a keyer tube (½ of a dual triode 6SL7 or 12AU7 tube). These two keyer tubes operate the tele-

[9]McCoy, J.L., "Radioteletype Conversion from Receiver I.F.," *QST*, Jan. 1960, p. 32.

[10]Bernstein, M., "An Inexpensive Radioteletype Converter," *QST*, Jan. 1953, p. 44.

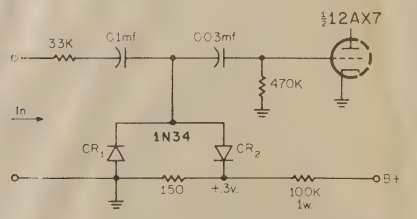


Fig. 4.2—Input circuit of the W2PAT converter shows the two 1N34 diodes used for clipping.

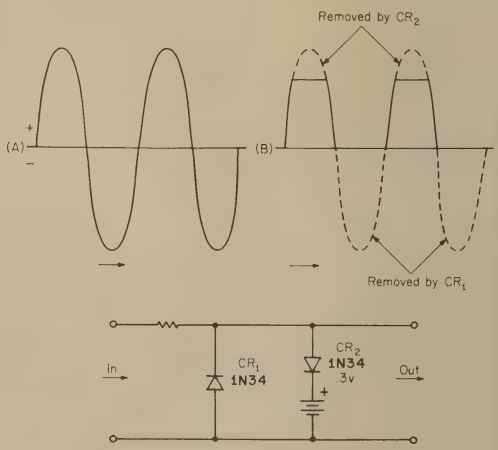


Fig. 4.3—Shown above is simplified version of the diode circuit shown in fig. 4.2.

type printer either directly or indirectly through the use of a relay.

The details of the input circuit of the W2PAT converter in fig. 4.2, showing diodes CR_1 and CR_2. Diode CR_2 is back biased 0.3 volt. The action of these two diodes limits the audio voltage to the grid of the 12AX7 tube to about 0.6 volt even when the audio voltage applied to this circuit is as high as 30 volts. The limited voltage applied to the grid of the 12AX7 varies from about 0.15 volt to 0.6 volt, for an input voltage variation of about 1 volt to 30 volts from the receiver output. A simplified version of the diode portion of the circuit of fig. 4.2 is shown in fig. 4.3. The wave from the receiver to the input of the limiter-clipper is shown in (A) of fig. 4.3 and the wave at the output of the limiter-clipper that is applied to the grid of the 12AX7 tube is shown in (B) of fig. 4.3. It will be noted that CR_1 removes the negative half cycles of the wave and that CR_2 clips off the top portion of the positive half cycles of the waves as shown in (B). Further inspection of (B) shows that the wave is now virtually a square wave and considerably reduced in amplitude. In practice the forward resistance of CR_1 is not zero, so not all of each negative half of the wave will be clipped. For the same reason all of that portion of the halves of the wave beyond the back bias of 0.3 volt will not be clipped, so in practice the output from this limiter-clipper circuit is almost 0.6 volt for an input voltage of 30 volts, as previously stated.

Further limiting and clipping as well as amplification and stabilization of the signals takes place in both halves of the 12AX7 limiter-amplifier stages. The output from the second half of the 12AX7 is a fairly constant 15 volts when the audio output signals from the receiver vary from less than 1 volt to 30 volts.

The limiter-clipper-amplifier functions of these two stages, especially the amplifier action, should be well known to most readers. However, it might be well to briefly cover the operation of triode tube clipper circuits. The basic triode clipper circuit is shown in its simplest form in fig. 4.4. When the positive peak of the input voltage wave exceeds the negative voltage of the bias battery C the net voltage on the grid is positive and grid clipping takes place. This action is similar to the diode clipping action on positive peaks just described and graphically illustrated in (B) of fig. 4.3. Negative peak clipping will occur when the input voltage is sufficiently large so that on negative peaks the negative signal voltage plus the negative bias voltage C, bias the tube to cutoff. That part of the negative half cycle, during which cut off condition exists does not appear in the output. Obviously, triode tube clipping has an advantage over diode clipping; you may accomplish clipping and obtain amplification of the signal at the same time. Although the output signal has been clipped, it is possible, with a triode tube clipper, for the output to exceed the amplitude of the input signal.

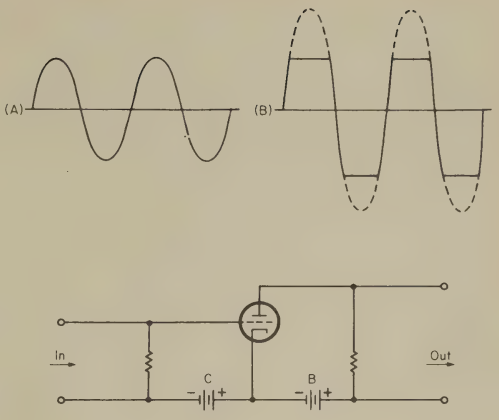


Fig. 4.4—Basic circuit of a triode clipper and its input and output waveforms. Note that the output while clipped is amplified.

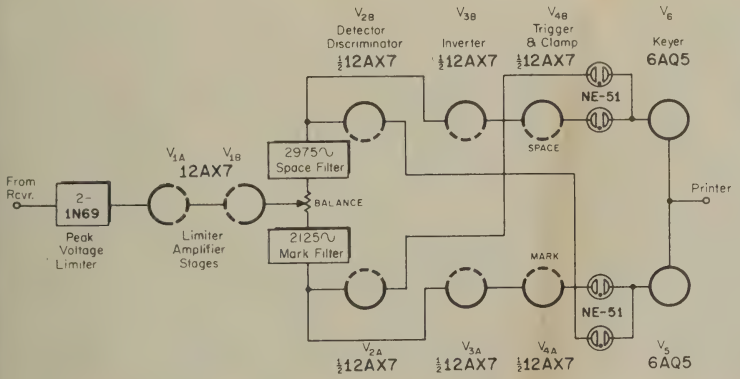


Fig. 4.5—Block diagram of the W2JAV converter described in the text.

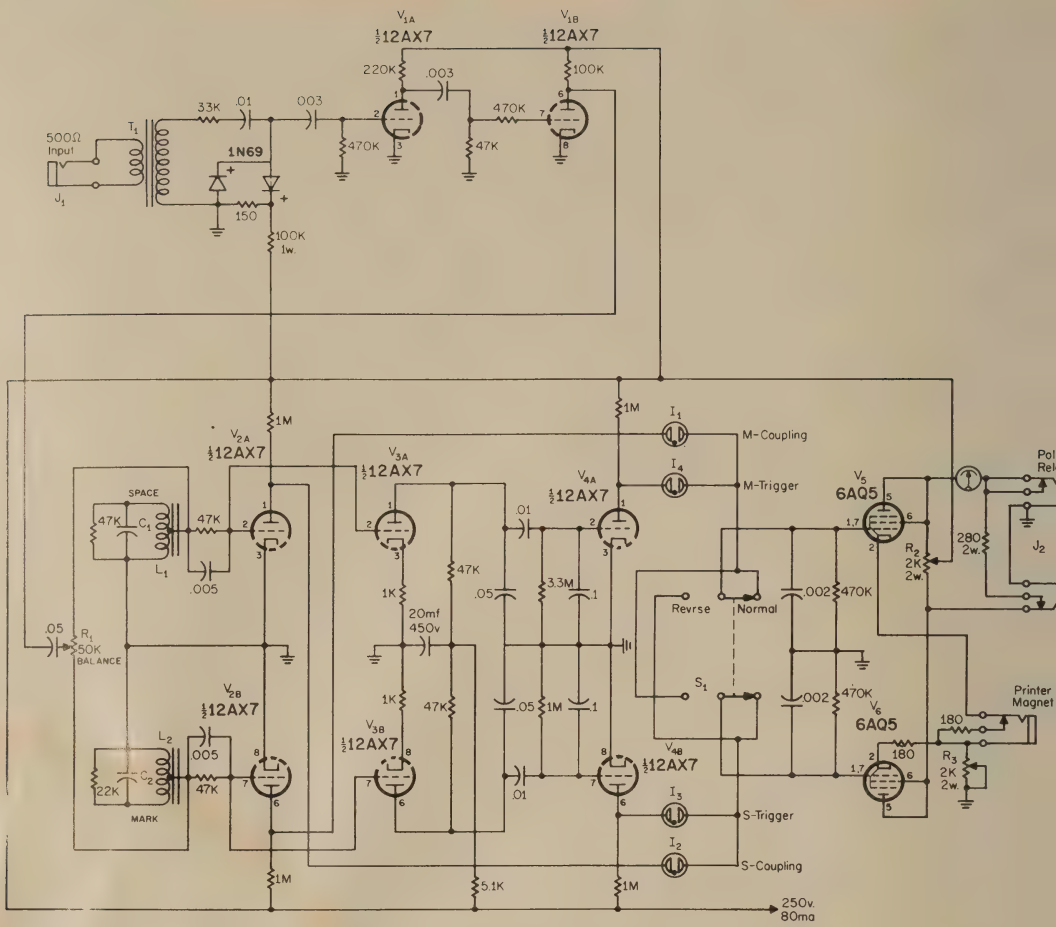


Fig. 4.6—Circuit of the W2JAV converter for RTTY work.

Now, let's partially repeat but at the same time amplify some details of the W2PAT converter already touched upon. At this point, it becomes necessary to separate the two audio tones, *mark* (2125 cycles) and *space* (2975 cycles). The 12AX7 detector stage is a dual grid leak detector stage with the signals fed to the input of both detectors. The input to one detector is supplied with an audio filter resonant at 2125 cycles and the input to the other detector is supplied with an audio filter resonant at 2975 cycles. The two signal tones are separated by means of these two resonant filters. The *mark* and *space* signals control the keyer tube, 12AU7. More on the keyer tube later. Coupling from each detector plate to the grids of the 12AU7 keyer tube is by means of a neon NE-51 lamp. These neon lamps act as switches which give a more positive demarcation between the *mark* and *space* pulses. W2PAT stated that the converter will operate from signals that are only 6 db above the noise level.

The design of the W2PAT converter is relatively simple compared to some other converters. A general outline of the W2JAV converter is given next. The actual operation of these two converters will be covered in detail later.

W2JAV Converter

The next important radioteletype converter after the W2PAT converter, that received wide spread attention, was the W2JAV Converter.[11] The W2JAV converter used the W2PAT basic circuit design but changed to 12AX7 tubes up to the keyer stage which was changed to two 6AQ5 pentodes. The basic difference between the W2JAV and W2PAT converters was that W2JAV added two dual stages between the dual

[11] Kretzman, B., "An Improved Radioteletype Converter," *CQ*, April 1958, p. 42.

detectors and the dual keying tubes. A block diagram of the W2JAV converter is given in fig. 4.5, which will give the reader a chance to compare it with the W2PAT converter shown in the block diagram of fig. 4.1. The complete circuit of the W2JAV converter is shown in fig. 4.6.

We have had much to say about upside down signals and turn-over switches, so it is doubtful if anyone had any difficulty in spotting S_1 as the TURN-OVER, or REVERSE switch in fig. 4.6, or have any doubts as to its purpose.

It will be noted that the circuit of fig. 4.6 indicates the use of a *polar relay*. This is a device not covered up to this point, although we did suggest the possible use of a relay in connection with frequency shift keying earlier when that subject was covered. The polar relay subject will be covered in detail later.

The W2JAV converter has improved selective filters as well as good limiting. The W2PAT converter used television width coils in the construction of the two tone filters (*mark*-2125 cycles and *space* 2975 cycles) whereas the W2JAV converter used toroidal wound coils which have a much higher value of Q than the conventional core type coils such as the television width coils. Naturally, the toroid-wound coils are much more selective and desirable. At one time toroid coils were not readily obtainable or well known in amateur circles. RTTY has changed this. These coils are now regularly advertised in many places and most any RTTY'er is acquainted with the superior merits of the toroid-wound coils. Another important feature of this converter, which is a carry-over from the W2PAT converter, is the BALANCE control (50K pot—R_1) which makes it possible to change the ratio of the *mark* and *space* signals being fed into the two tone separating filters.

A significant difference between the W2PAT converter and the W2JAV converter is that the latter added two stages (dual) that the reader has probably already noticed from a comparison of their respective block diagrams. The first added dual stage (V_{3A} and V_{3B}) is an inverter stage. The second added dual stage (V_{4A} and V_{4B}) is a trigger and clamp stage. Original credit for this circuitry goes back to T. W. Groger, W7HJC.[12] This added circuitry in the W2JAV converter is perhaps the most important feature, which gives it the ability to copy on *mark only* or *space only*. This is a very desirable feature, almost a must in any modern terminal unit. The probability of losing both the *mark* and *space* signal at the same time in a crowded band is certainly not as great as losing one or the other at a time. With the ability to copy on one alone, you can lose first one and then the other and keep right on copying. The W2JAV converter has been, and still is, a popular converter. It is simple, inexpensive, and easy to build. It will copy shifts that are less than 850 cycles but with diminishing success as the shift is reduced.

It will be noticed that, for the greater part, both the W2PAT and the W2JAV converters, discussed previously, or any converter for that matter, are dual channel devices. The two RTTY signals enter the amateur's receiver, pass through and leave the receiver together (except that they are not both on at the same time) and enter the converter together. Both signals, (*mark* and *space*) are first clipped, limited and amplified as previously described. At this point, the two signals are separated and the dual facilities design of converters comes into being.

The two RTTY signals are identical when leaving the transmitter except for frequency and coded sequence, so it is desirable that they keep their same related status on to the teletype printer mechanism at the receiving end. This is necessary in order that the transmitted message be received without errors. In practice, the interrelationship of the two signals may start changing the moment they leave the transmitter. Actually, this can even happen in the transmitting process if all is not in order at the transmitter end. In traversing the distance from the transmitting point to the receiver location, the signals may be changed in time and/or amplitude relationship with respect to each other.

The purpose of the clipping and limiting, as previously described, is to restore the original signal amplitude relationships shifted by changes that may have taken place in transit from the transmitter to the receiver. The function of clipping and limiting is necessary for proper action in the detectors that follow. More on this later.

Mark And Space Filters

The RTTY signals have been traced from the transmitter, through space, through the receiver, into the converter, through the clipping-limiting and amplifier stages of the converter to the filters that separate the two tone signals. Each tone filter consists of an inductor and capacitor connected in parallel. The two tone frequencies used in these two converter designs are 2125 cycles (*mark*) and 2975 cycles (*space*). In fig. 4.6 inductance L_1 *and* capacitance C_1 resonate at the *space* frequency of 2975 cycles, placing this *space* signal voltage on the grid of V_{2A}. This same filter rejects the *mark* frequency of 2125 cycles. Likewise, inductance L_2 and capacitance C_2 resonate at the *mark* frequency of 2125 cycles and reject

[12] *RTTY*, June, 1956, W6AEE.

the *space* signal so only the *mark* signal appears on the grid of V_{2B}.

Pulse Modulation

The detector tube for the *space* signal is V_{2A} and V_{2B} is the detector tube for the *mark* signal. From our past experience, the word *detector* suggests the separation of *intelligence* from a carrier. A detector is a device whose output is not exactly proportional to its input. Such a device is *nonlinear*. This is not to be confused with *detector linearity* which is a measure of a detector's ability to reproduce, at its output, an exact replica of the modulation that is present on the carrier signal fed into the input of the detector. In this case, the *space* signal carrier is 2975 cycles and the *mark* signal carrier is 2125 cycles. The intelligence is certainly not in the amplitude of either signal as all amplitude variations were effectively taken out of both signals before either reached their respective detectors. This was done in the clipper-limiter stages. Obviously, then the intelligence is in the *presence* and *absence* of each signal. Some call this system *code modulation* while others call it *pulse modulation.*

From our knowledge and experience with modulated carriers, we know that detector circuits remove the carrier leaving only the modulation envelope which, in this case, is a square wave whose frequency is approximately the *baud*[2] *rate* divided by two. In amateur radio teletype with a code speed of 60 w.p.m. this means 45.45/2 = 22.775 or 23 cycles for all practical purposes. Figure 4.7 shows the time relationship between the *mark* signal (A) and *space* signal (B) at the input circuit of their respective detector tubes and the resultant signal (C) at the output of the converter forming the teletype code for letter "R".

Detectors

The dual detectors in both the W2PAT and W2JAV converters are of the *grid rectifying* type. To some, this detection process may be better known by another name, grid leak detection, which was very popular in the early days of radio. Detection is based on the grid leak resistor and capacitor as shown in the grid circuit of V_{2A} and V_{2B} of fig. 4.6. As an r.f. detector in the early days of radio, the capacitor C was in the order of 0.00025 mf and the grid resistor R, across it, ranged from 1 to 3 megohms. The linearity of such a detector improves as the grid resistor is reduced and the amplitude of the signal being detected is increased. Under such circumstances the detector acts as though it were a diode followed by an amplifier stage. The detector grid resistor in both converters is only 47K.

A word now as to how the circuit detects.

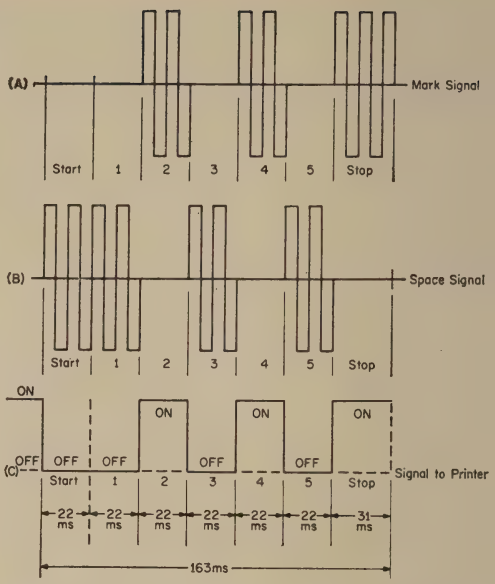


Fig. 4.7—(A) *Mark* signal at the input circuit of detector tube V_{1A} and (B) *space* signal at the input circuit of detector tube V_{1B}. (C) Signal to teletype printer at the output of V_5 and V_6 forming teletype code for letter "R".

The positive halves of the input signal make the grid positive, thereby attracting electrons to the grid from the cathode. The electrons charge the capacitor C which then discharges through R on the negative half of the cycle. If the time constant is correct the voltage across R can be equal to the peak of the input signal. The polarity of the voltage drop across R makes the grid negative with respect to the cathode.

The presence of the grid resistor, as well as its selected value, and the strength of the signal makes it possible to control the plate current cut-off of the tube. It will be recalled that all amplitude variations of our RTTY signals were eliminated by the clipper-limiter stages that precede the detectors and our signals to be detected are simply pulses of 2125 cycles and 2975 cycles as determined by the teletype code sequences being transmitted. (Assuming no interference.) It can be seen that, on the negative half cycles of our RTTY signal pulses, that no grid current flows nor is the plate circuit particularly affected because of the action of the grid capacitor and grid resistor.

W2PAT Detector

The presence of a *mark* signal on the grid of the *mark* detector tube of the W2PAT converter will cause a flow of grid current (caused by the positive half cycles) resulting in a negative grid bias sufficient to cause plate current cut-

off. This, in turn, causes a rise in plate voltage sufficient to cause the associated neon lamp to fire. As a result, the half of the 6SL7 keyer tube connected to this neon bulb has about 25 volts of positive bias applied to its grid, causing this triode half to operate a polar relay and at the same time biasing (through a common 1000 ohm cathode resistor) the other half of the 6SL7 tube *space channel*) to cutoff. The rest of the circuit can be very simple. The selector magnet of your machine and a voltage source in series with the polar relay contact and a current limiting resistor can complete the circuit. See fig. 3.1 The *space* signal and its associated channel (duplicate of the *mark* channel) operates similarly on the other winding of the polar relay, pulling its armature in the opposite direction opening the relay contact. More on the polar relay later.

W2JAV Converter

The *grid rectifying* detector tubes V_{2A} and V_{2B} of the W2JAV converter work the same as the grid rectifying detector tubes of the W2PAT converter. From here on the W2JAV converter functions somewhat differently. As pointed out earlier, the W2JAV converter detectors are followed by a dual inverter stage which is, in turn, followed by a dual trigger and clamp stage driving two 6AQ5 keyer tubes. The *mark* channel feeds into the grid of one of the 6AQ5's and the *space* channel feeds into the grid of the other 6AQ5. The cathode of each 6AQ5 has a 180 ohm resistor with the bottom end of the two resistors joined. A 2K variable current limiting resistor, R_3, is connected from this point to ground as shown in fig. 4.6. The purpose of this resistor is to set the teletypewriter magnet coil and/or polar relay coil current to its proper value. The teleprinter magnet coils plug into jack J_3, and the polar relay plugs into jack J_2 using only the two tips of J_2 as illustrated in fig. 4.8.

As has been observed, one may operate a teletypewriter selector magnet coil directly by plugging into jack J_3 or indirectly by relay control by plugging into jack J_2. When jack J_3 is used, the plate current of the two keyer tubes V_5 and V_6 properly control or operate the selector magnet coils while resistor R_3 is used to adjust the selector magnet coil current to its proper value.

Inverter Stage And Trigger-Clamp Stage

In the coverage of detector action (same for both converters) it was pointed out that the positive half cycles of either the *mark* or *space* signals on the grid of their respective detector tubes created a negative bias causing the voltage at the plate to rise. This fired the neon lamp coupling the detector tube plate to the

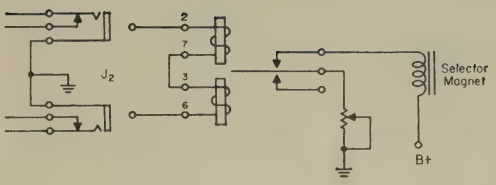


Fig. 4.8—Illustration showing how a polar relay such as a Western Electric type 255A may be plugged into jack J_2 of the W2JAV converter and operate a teletypewriter selector magnet coil.

keyer tube grid. This puts positive voltage on the grid of the keyer tube causing it to draw plate current to operate a polar relay or a printer magnet directly. In the case of the W2PAT converter, the 6SL7 double triode tube was the detector tube (two detectors—½ as the *mark* signal detector and the other half as the *space* signal detector).

A *mark* signal on the grid of detector tube V_{2B} of the W2JAV converter gives it negative bias, causing the voltage at plate of V_{2B} to rise to the value required to fire neon lamp I_1 (NE51). This puts a positive bias on the *mark* keyer tube V_5 (6AQ5) causing it to draw plate current to operate a polar relay (jack J_2) or printer magnet (jack J_3.) The plate and screen voltage of both keyer tubes (*mark* and *space*) are selected so that the tubes are at approximately plate current cutoff when no signal is present at the grid of either tube. Likewise, a *space* signal on the grid of its detector tube V_{2A} gives it negative bias causing voltage at plate of V_{2A} to rise to the voltage required to fire neon lamp I_2. This puts positive bias on the *space* keyer tube V_6 (6AQ5) causing it to draw plate current. This does not cause the printer magnet to function since it is in the cathode circuit of the *mark* keyer tube V_5. This does, however, cause the polar relay to operate. See fig. 4.8

It will be noted from fig. 4.6 that the grid of the *mark* detector tube V_{2B} *is* tied directly to the grid of *mark* inverter tube V_{3B}. This may appear to form some sort of a dual detector situation so let us follow the action, step-by-step. The positive half cycles of the *mark* signal to the grid circuit of detector tube V_{2B} causes grid current to flow placing a negative bias on V_{2B} as covered in the description of the tube as a detector. One might argue that the identical thing happens to V_{3B} except that V_{3B} has a 1K bias resistor and its plate voltage is much higher (note the value of plate resistors for each tube) so the two tubes are not operating

under the same conditions. Suffice to say that the negative bias present at the grid of V_{2B} is also present at the grid of V_{3B}. This means that the plate of V_{3B} is made positive (inverted). This is a pulse signal (*mark*) which through the action of the 0.01 mf coupling capacitor, associated resistors, and 0.1 mf capacitor appears on the grid of V_{4B} which is the *space* trigger tube. This positive signal on the grid of V_{4B} would tend to cause the tube to draw current lowering the voltage at its plate below the voltage required to fire neon lamp I_3 (NE51). An inspection of the circuit of V_{4B} makes it obvious that the tube must have already been drawing sufficient plate current so that the voltage at its plate was already below the voltage required to fire neon lamp I_3. All of this simply sums up to the fact that the *mark* pulse had no effect upon *space* trigger tube V_{4B}.

Copying On One Tone

Now let us see what happens when there is no *mark* signal at the grid of *mark* signal detector V_{2B} or mark inverter tube V_{3B}. This is during the time that there is or supposed to be a *space* signal at the grid of *space* signal detector V_{2A} and *space* inverter tube V_{3A}. Since the negative bias (caused by a *mark signal*) is no longer present to heavily bias or cut off the plate current of V_{2B}, the voltage at its plate does not rise to fire neon lamp I_1. Neither does the voltage at the plate of the mark inverter tube V_{3B} rise. To the contrary, in the absence of heavy bias on the grid of V_{3B} its plate current goes up and the voltage at its plate goes down instead of up, thereby placing a negative charge or pulse on the grid of space trigger tube V_{4B}. This causes the voltage at the plate of V_{4B} to increase to a value that will fire neon lamp I_3. This, in turn, places a high positive voltage on the grid of the *space* keyer tube V_6 causing it to draw plate current. From the above, it has been shown that even if the *space* signal does not show up at V_{2A} and cause I_2 to fire when the *mark* signal ends at V_{2B}, that the space keyer tube V_6 will be keyed just the same but by I_3 because of the *lack of a mark signal* at V_{2B}.

The action of V_{2A} and V_{3A}, in the presence of a *space* signal, and their effect on keyer tubes V_5 and V_6 is similar to the action of V_{2B} and V_{3B}, in the presence of a *mark* signal, just described in detail. Obviously, when both the *mark* and *space* signals are present and of sufficient strength to properly operate their respective detectors, the inverter and trigger stages are somewhat superfluous. The presence of a *space* signal at the *space* detector tube V_{2A} will cause neon bulb I_2 to fire, keying *space* keyer tube V_6. The presence of a *mark* signal at the *mark* detector tube V_{2B} will, in turn, cause neon lamp I_1 to fire, keying *mark* keyer tube V_5. The firing of neon lamp I_1 results in a positive voltage being developed and applied to the grid of *mark* keyer tube V_5 which causes its plate circuit to conduct (key). The instant the *space* signal (preceding the *mark* signal) ends at the grid of V_{2A}, the plate current of space inverter tube V_{3A} goes up and the voltage at its plate goes down (as described for V_{3B} when *mark* signal ended) placing a negative charge or pulse on the grid of mark trigger tube V_{4A}. This causes the voltage at the plate of V_{4A} to increase to a value that will fire neon lamp I_4. The firing of neon lamp I_4 places a positive voltage on the grid of *mark* keyer tube V_5 the same as the firing of neon lamp I_1 as above outlined. This then results in a duplication of action at the grid of keyer tube V_5 when there is a *space* signal present and followed by a *mark* signal. If the *mark* signal failed to appear, following a *space* signal then V_5 would be keyed just the same producing a *mark* signal to operate the printer. This is, in effect, a back up of the *mark* signal by the *space* signal. Likewise, you have a back up of the *space* signal by the *mark* signal.

Discussion Of One Tone Copying

When one first reviews this scheme of printing, this printing of characters correctly even though all of the signals representing the five elements are not actually present, it may appear that we have some form of near perpetual motion; well, not quite. So long as you have one signal or the other (*mark* or *space*) the converter has the faculty to keep copying on the one signal keying both the *mark* and *space* keyer tubes. Let us assume that we have perfect conditions with no annoying atmospheric noise, man-made noise or interfering signals—just the two tones that we desire to copy. If one tone fades away, the converter will continue to operate the teletype printer so long as the other tone remains. If both tones fade out, it can be seen that the charges on the various grids start dissipating since all grids have a return path to ground through a resistor. With a dissipation of these charges, the teletype machine connected to the converter will run "open" as previously described. In the description of the operations of the machines and the teletype code, it will be recalled that it stated that each teletype character ended with a *mark* pulse as graphically illustrated in fig. 1.2. Under normal conditions, when the *mark* tone is being received, there is no problem of the machine running open with this converter. The grid of the *mark* trigger tube V_{4A} has a 3.3 megohm resistor which provides for a longer time constant. This keeps the printer from running open during short intervals of no signals or a temporary

absence of a *mark* signal during periods when no characters are being transmitted. This *mark*-hold feature is certainly one to be desired in any converter.

With the desired tone gone the channel is now susceptible to any signal (man-made or otherwise) that may come along. Wouldn't it be wonderful if the converter channel would also disappear when its signal disappeared? Then it wouldn't be around to clobber what's left of the system. Oh yes, the channel must also reappear just as fast as it vanished when and if the signal reappears. Unfortunately, that takes a lot more doing and this converter doesn't solve this problem.

The operator does have a choice of manually selecting either the *mark* or *space channel* (or both) by use of the balance control R_1. In its mid, or balanced position, the converter is set to copy both signals. Turning the control all the way to the right favors the *mark* signal and all of the way to the left favors the *space* signal.

From the preceding discussion it becomes apparent that this converter doesn't always copy on one tone alone when the other tone disappears. Whether it does so depends not only on the condition of the tone remaining but also on what goes on in the channel of the missing tone. If one tone only partially goes away then you have a much better chance that the converter will continue to function properly. If one tone disappears altogether and the other tone becomes weak, then there is a possibility that the limiters will be captured by any heavy noise or interference to cause printing errors up to one hundred per cent. This leads up to the point that *interference rejection must be made prior to limiting*. A review of figs. 4.5 and 4.6 shows that this converter makes no provision for this as the signals to the converter are fed directly into limiter stages. With this converter you are dependent upon whatever selectivity your receiver has to fight the interference problem. Practice indicates that you not only need a good receiver but also anything else that can help with the interference problem. For some time there has been a growing demand by the RTTY'ers for a converter with a greater selectivity than the W2JAV readily provides.

5

POLAR RELAYS AND DISTORTION

IT was noted in the discussion of the two early converters that polar relays were used in both units. Polar relays are still used extensively in connection with RTTY converters. They are also used extensively in connection with transmitter frequency shift keying circuits. In fact, polar relays are very much a part of RTTY work. Therefore, this all-important subject should be thoroughly covered before going further.

The polar or differential relay as it is sometimes called, has amateur applications other than in RTTY work, such as transmitter keying circuits as well as many commercial applications. Before we go into the why of polar relays, we might ask what a polar relay has that most other relays don't have. One answer to this might be, "Nothing really, except that it does it better than most other relays." Another answer might be, "It has a weightless (almost) armature and a high sensitivity." The question might also be answered with a negative statement: "It doesn't have something that most other relays do have. That something is a spring to hold the armature contact to one side or the other." In other words, a polar relay has no *mechanical biasing spring* on its armature. These answers should give you some idea of why the polar relay is generally considered as something special.

Why A Polar Relay

Relays, *per se*, are not new to the amateur; they have been with us for a long time. However, one can recall when turning it back to the other fellow was somewhat of a ritual. It was more like a missile firing countdown with all of the switches that had to be thrown. Then relays, at a price that the amateur could afford, became more plentiful.

In most radio amateur applications, the requirements of a relay are relatively simple. It needs to pull in readily when its coil is energized and turn loose as readily when the circuit energizing its coil is opened. The turning loose part in common relays is aided by means of a spring. Not so for a polar relay because it *has no* armature biasing spring.

The amateur is acquainted with the need to use a relay for the closing and opening of electrical circuits. This need also exists in the operation of teletype machines and in the frequency shift keying of transmitters. The requirements of a relay in this service are far more exacting than for a relay for switching the antenna, muting the receiver and a multitude of other services.

One might be inclined to consider that a relay is simply a device with a coil to be energized which, in turn, causes an armature to open and close electrical contacts. A polar relay is more than that. It approaches more the role of being, in a true sense, a *relay* or *repeater* of data or information given to it. That is what sets it apart from the ordinary relay. On the other hand, we should not lose sight of the fact that it is a mechanical device and its armature is not quite "weightless" so it is not

altogether a perfect device. However, when a polar relay is properly adjusted it does an excellent job of truly being a relay.

Basic Construction

The construction of a polar relay is a bit more complicated and detailed than an average relay. For one thing, it is built to closer tolerances and has many mechanical refinements. Its armature is very light and is also relatively long and thin. This minimizes the effects of inertia and thus contributes to its accuracy as well as sensitivity.

Figure 5.1 shows a simplified version of the basic mechanical construction of a polar relay. Let us inspect it in detail. The basic parts of a polar relay are a permanent magnet, an armature and two or more coil windings. In addition there are two contacts that the armature alternately connects with, a special base with contact pins and permanent magnet extension bars. There are also adjustable pole pieces that can be screwed in or out to change the spacing between them and the armature. There are still other parts whose function are secondary but necessary. They are mostly associated with the mechanical fabrication and refinements of the relay, as well as for mechanical rigidity.

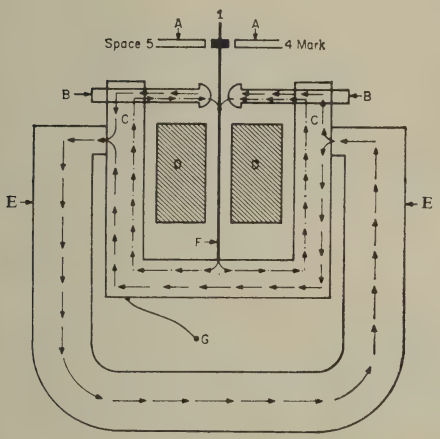


Fig. 5.1—Simplified mechanical construction of a polar relay showing the direction of magnetic lines of force. The permanent magnet flux path is shown by the dashed line while the flux path due to the current in a coil winding is shown by the dot dash combination. Parts identified are:

A—Contact connections, B—Adjustable pole piece (screws), C—Permanent magnet extension pieces, D—Coil windings, E—Permanent magnet, F—Armature, G—Armature connection.

Theory Of Operation

The operation of the polar relay can best be visualized by viewing its simplified basic outline given in fig. 5.1. Consider first that no voltage is being applied to either of the coil windings. Consider further that the armature is reasonably positioned in the center of the coils and that the permanent magnet, the yoke, and permanent magnet extension pieces are fairly symmetrical with the armature. This is taken care of in the design and construction except for minor adjustments. Under the above conditions it should be possible to adjust the two pole pieces so that the armature floats between them. In other words, there would be a condition existing where the pull on the armature to either side would be the same.

If a voltage is now applied to one of the windings (either one) it will cause the armature to snap to one side or the other. The direction depends on the polarity of the applied voltage. A reversal of polarity creates a reversal of the direction of current flow through the coil and causes the armature to snap to the other side.

The effect of applying a voltage to one of the coil windings is indicated by showing the resultant lines of flux about the coil, in the armature, yoke, permanent magnet extension pieces and the adjustable pole pieces. It will be noted that the coil flux lines are additive with the permanent magnet flux lines in the right-hand adjustable pole piece and oppose the permanent magnet flux lines in the left-hand adjustable pole piece. The result is that the magnetic pull on the armature from the left-hand pole piece will decrease and the magnet pull on the armature from the right-hand pole piece will increase. This simply means that the armature will move to the right making connection with contact 4, which we will arbitrarily call the *mark* contact.

A reversal of the voltage would change the direction of current flow and the opposite would be true, the magnetic pull on the armature from the right-hand pole piece would decrease and the magnetic pull from the left-hand pole piece would increase, pulling the armature to the left. Contact would now be made to the *space* terminal.

Basic Polar Relay Circuit

Obviously, no advantages would come from a continued manual reversal of the voltage leads to the polar relay coil as outlined above. However, this principle does have an application in land-line polar telegraph circuits as well as land-line polar teletype circuits.

Perhaps you have been wondering about the other coil winding that the polar relay has. It was pointed out earlier that the polar relay has

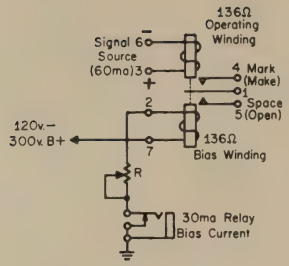


Fig. 5.2—Schematic symbol and electrical data for the Western Electric Type—255-A polar relay. The value of *R* is discussed in the text.

a spring to pull or mechanically bias the armature to one side. The other coil winding is used to do this electrically and do it better than any mechanical spring could ever do it.

The circuit of fig. 5.2 shows how the polar relay may be connected so that one winding is used as a bias winding and the other winding is used as an operating or keying winding. The value of the current limiting resistor *R* depends upon the B+ voltage selected. The value of *R* is adjusted so that the bias current is approximately 30 ma and should be in the order of 2000 ohms or more. After a quick mental calculation one may wonder why we don't use about 4 volts at the B+ point and little or no resistance for *R*. One should go back and read the section on "Selector Magnet Current" for a detailed answer to this question. Figure 5.2 may be compared to fig. 3.1 covering the circuit of a selector magnet.

A fixed current of 30 ma in the bias winding of the polar relay in fig. 5.3 pulls the armature to one side or the other depending upon the direction of the current flow. This position is normally the *space* position. The armature will stay in this position until a current in the signal winding creates a magnetic field of sufficient magnitude to swing the armature to the other side, normally the *mark* position.

The direction of the current in the signal winding has to create a magnetic field in opposition to the field created by the bias winding. The *magnitude* of the signal current must also neutralize the effect of the bias winding current and have *enough* magnetic force left to move the armature to the *other* side. Since it is considered desirable to have 30 ma of current in the bias winding to properly hold the armature to one side, it would seem reasonable that it would take 30 ma to neutralize this pull and also take an additional 30 ma to move the armature to the other side. That is the case; it is desirable that the signal current be in the order of 60 ma. As in the bias winding circuit (fig. 5.2) and the selector magnet circuit (fig. 3.1) it is necessary that the circuit voltage be in the order of 120-300 volts with an adjusted circuit resistance so that the current is 60 ma.

A reversal switch at this point in the circuit could shift the order of *mark* and *space*. An occasion for this would be when the incoming signal is being sent "upside down" and reversal is necessary.

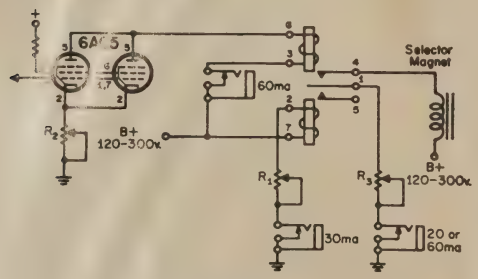


Fig. 5.3—Typical application of a polar relay in receiving. In actual practice there would probably be added circuitry as noted in the text.

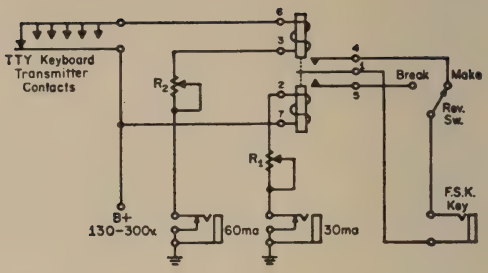


Fig. 5.4—Typical polar relay circuit for frequency shift keying of a transmitter. Resistors R_1 and R_2 are adjusted for the currents shown.

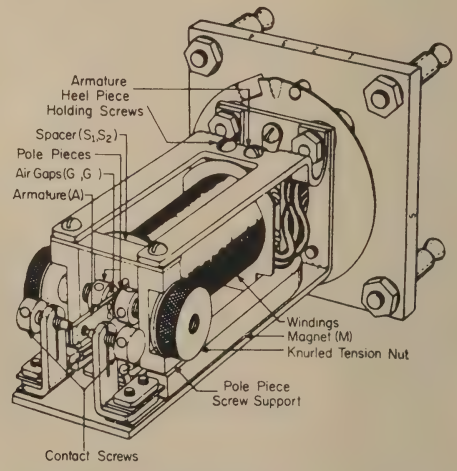


Fig. 5.5—Drawing of the 255-A polar relay show the details of its mechanical construction. A cylindrical dust cover fits securely over the forward end of the relay.

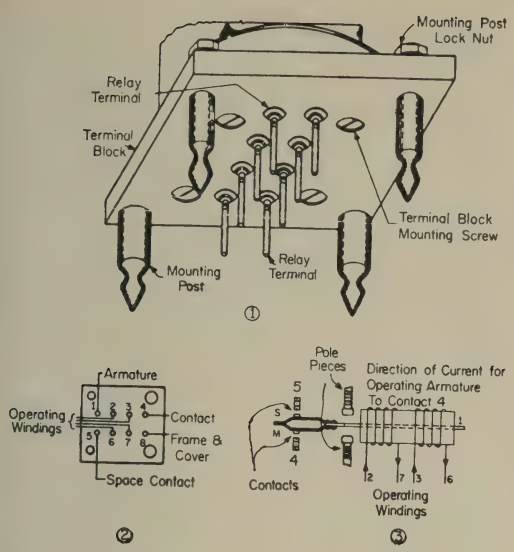


Fig. 5.6—(1) Base view of the 255-A polar relay; (2) Base connection prongs; (3) Coil and contact arrangement.

Typical Polar Relay Circuits

The polar relay circuit shown in fig. 5.2 may be used in connection with an RTTY converter for receiving or it may be used in the frequency shift keying of a transmitter. Such circuits, not only involving the polar relay, but the selector magnets and the keyboard contacts of a teletypewriter as well, are usually referred to as "local loops." Figure 5.3 shows how the polar relay circuit of fig. 5.2 might be adapted to an RTTY converter keyer stage using a pair of 6AQ5's connected in parallel. The resistance R_1 is adjusted so that the bias winding (terminals 2-7) receives 30 ma. The resistance of R_2 and the screen voltage are adjusted so that

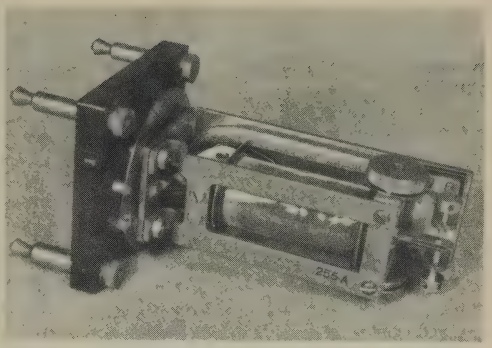


Fig. 5.8—View of a 255-A relay showing general construction details.

the operating winding (terminals 3-6) passes 60 ma when the two keyer tubes of converter are conducting on *mark*. The resistance of R_3 is adjusted for either 20 ma or 60 ma depending upon whether the two selector magnet windings are connected in series or parallel. In actual practice there would probably be added circuitry, especially in the 1-4 contact key circuit.

The question might well be raised as to why use a polar relay such as in the W2JAV converter or in a circuit such as fig. 5.3 when in each case the selector magnets may be placed in the circuit directly. There *are* arguments for both sides. The decision of an operator to use the polar relay probably hinges more on the individual, his own particular local loop circuit, the number of teletype machines and terminal distributor machines he uses as well as how he uses them. Some varied uses were briefly mentioned under Model 14 Transmitter Distributor in an earlier chapter. This subject will be covered in greater detail later.

The use of a polar relay, can lend convenience as well as flexibility to one's RTTY activ-

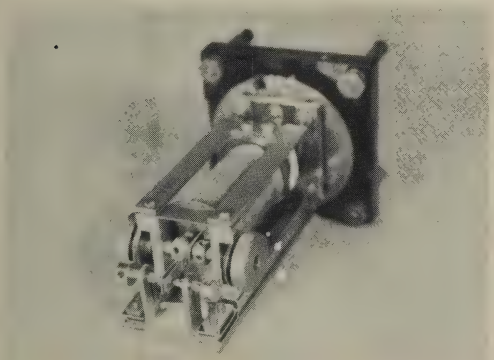


Fig. 5.7—General view of a Western Electric 255-A polar relay with the dust cover removed and properly oriented for mounting.

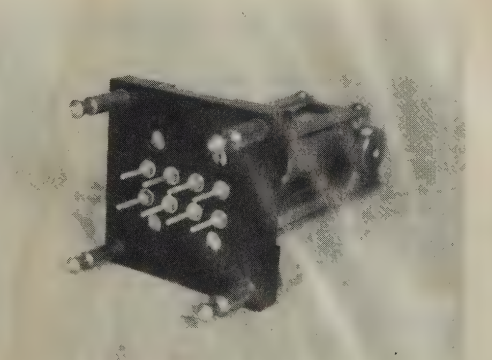


Fig. 5.9—Base view of the 255-A polar relay showing the arrangement of the contact pins and mechanical guide posts.

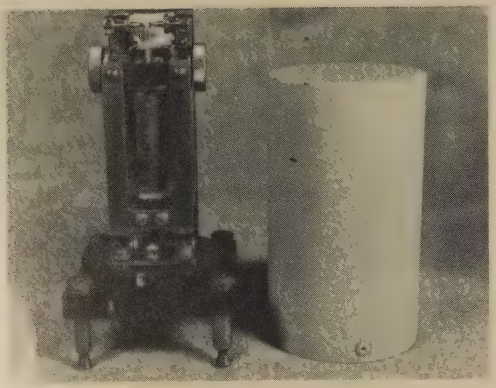


Fig. 5.10—View of what should normally be the horizontal plane of the 255-A polar relay.

ity. Also, we might add, that it acts as a good low pass filter by favoring and passing only the keying spectrum while discriminating against the higher frequency noise pulses.

FSK

Figure 5.4 shows how the polar relay circuit of fig. 5.2 might be adapted to the frequency shift keying of a transmitter. This circuit could be used to key any of the several frequency shift keying circuits outlined previously. It will be noted that a single pole double throw switch is included so that the keying of the transmitter may be reversed if necessary.

Relay Types

Figures 5.5 and 5.6 show the details of construction of a Bell Telephone System type 255-A polar relay. Views of the 255-A relay are given in figs. 5.7, 5.8, 5.9 and 5.10. One should have no difficulty in locating the long horse shoe or tuning fork type permanent mag-

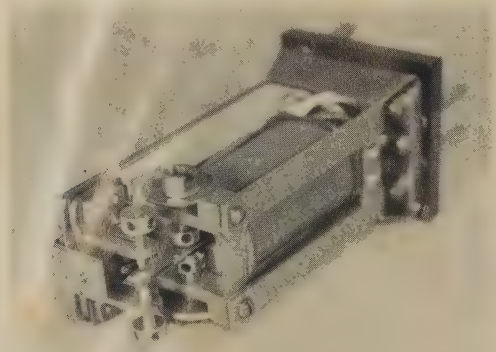


Fig. 5.11—View of the Western Electric D-164816 polar relay lying on its side showing the face. Note its close similarity to the 255-A polar relay. The D-164816 polar relay uses a rectangular dust cover.

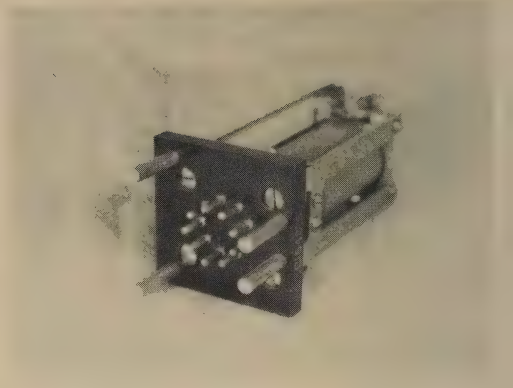


Fig. 5.12—Base view of the D-164816 relay shows the pin arrangement that fits a standard nine pin socket.

net located flat against the long portion of the L shaped mounting bracket. The two permanent magnet extension pieces are to be seen extending at right angles from the ends of the "horse-shoe" or U-shaped permanent magnet. The opposite ends of the permanent magnet extension pieces connect to one end of the yoke. The armature, contacts, and the two adjustable pole pieces should be just as easy to locate and identify.

Figures 5.11 and 5.12 are views of a polar relay advertised on the surplus market as a Western Electric D-164816. The armature, permanent magnet and other parts for the magnetic circuit are essentially the same as for the type 255-A polar relay, as can be seen by comparing figs. 5.11 and 5.12 to figs. 5.7 to 5.10. This relay has a base contact pin arrangement that fits a standard nine pin socket. In addition, the dust cover is rectangular whereas the dust cover for the 255-A is cylindrical. A further difference between the Type 255-A and the Type D-164816 polar relays is that the latter has three coil windings as shown in fig. 5.13.

Relay Mounting

An inspection of the drawings and actual photographs of the two polar relays under discussion indicates that the relays have mechanical guide pins as well as electrical contact pins on the base. Two of the guide pins on the 255-A polar relay are of one size (see right pins of fig. 5.9) and the other two are of a smaller size. This permits insertion of the relay one way only. The ends of the guide pins are shaped the same as the end of a standard phone plug. The socket for a 255-A relay has V-shaped metal springs that fit into these indentations on the ends of the guide pins. It requires a special socket to fit the electrical pin arrangement of the 255-A relay as well as its mechanical guide and hold pins. These sockets are usually available on the surplus market

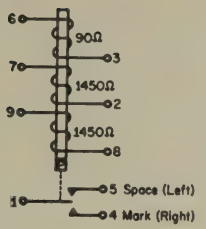


Fig. 5.13—Coil and terminal data for the Western Electric D-164816 polar relay. Application of the positive voltage to terminals 2, 3, or 8 moves the armature to the mark side (1 to 4). Data supplied by Todd Electronics Co., Omaha, Nebraska.

from the same sources that advertise the relays. There does not seem to be a special socket available to fit the nine pins of the D-164816 relay and, at the same time, accommodate the four mechanical guide pins as shown in figs. 5.12 and 5.13. The best thing to do is to use a standard nine pin socket for the electrical contact pins and drill the chassis, in which the socket was mounted, to accommodate the four mechanical guide pins. When mounted in the proper place for best results, the "face" of a polar relay should face horizontally and not vertically. At the same time it should not be mounted on its side. Figure 5.7 shows the proper orientation of a polar relay for mounting.

Figure 5.10 shows a view of the 255-A polar relay looking down on its "top" or horizontal plane. It is usually recommended that this and similar polar relays be mounted in this plane for best results. All views of the polar relay are with the bakelite or fiber dust cover removed in order to show the detailed construction of the relays. Normally these covers should stay in place at all times, being removed only when inspection or adjustments are in order.

Availability

The Western Electric Type 255-A relay is perhaps the easiest to obtain on the surplus market or from one of the state RTTY societies so it is the most popular as well as the most common. The Western Electric type 215-A polar relay is also occasionally available although it was not as accurately built as the type 255-A that followed.

The type 215-A has two coils whose d.c. resistance is approximately 90 ohms each, while the resistance of each coil of the type 255-A polar relay is approximately 136 ohms. The Western Electric D-164816 polar relay has three coil windings whose d.c. resistance are respectively 90 ohms, 1450 ohms and 1450 ohms.

Polar Relay Adjustment

The greatest advantage is obtained when the polar relay is used for transmission. It is possible, as explained earlier, to frequency shift key a transmitter with the keyboard transmitter mechanism directly, either dry or wet method. Unfortunately, however, the keyboard contacts do not provide clean keying but introduce a problem called *fortuitous distortion* and the operator will be completely unaware of it. A discussion of this problem will be presented later.

Reception with the use of a polar relay poses a problem of hash. The contact arcing produces r.f. interference that can be a problem when trying to pick up weak signals. It is possible to install a hash filter[13] across the polar relay contacts which will effectively suppress this interference. This circuit is shown in fig. 5.14.

The component values are not particularly critical but they should be mounted close to the polar relay socket with the shortest leads possible.

In some respects it can be considered that the polar relay is fairly rugged considering its sensitivity, precision and speed of operation. Even with only a casual inspection one cannot help but realize and appreciate the superior qualities of this relay. Relays that have provisions for mechanical adjustments are not too common to amateur radio and might cause the average amateur to shy away from its use. This is certainly understandable because adjustments on a special piece of gear, such as a polar relay, usually requires special tools or test equipment as well as special skills.

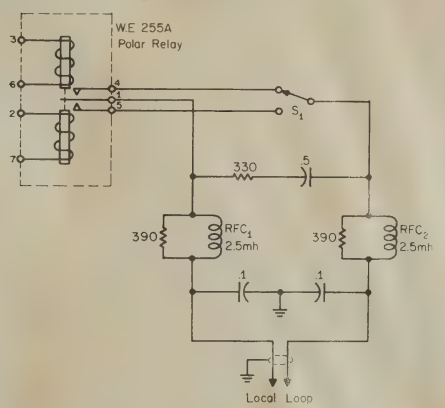


Fig. 5.14—Circuit of a polar relay hash filter that may be needed when the relay is used for RTTY reception. Switch S_1 is for reversing action.

[13]RTTY Column, Kretzman, B., *CQ*, August 1961, p. 102.

Fig. 5.15—Homebrewed Polar Relay Test Set made in two sections. The relay test socket is separated from the main unit by a four foot cable.

The adjustment of a polar relay probably requires as much patience and careful handling as it does skill. The availability of one or two special tools as well as a volt-ohmmeter also helps. The additional availability of a special polar relay test set, such as the one covered in detail later on, should make the job of adjusting your polar a pleasant and interesting experience, instead of a rather distasteful and painstaking chore.

Bias Distortion

It is not sufficient for the armature of a polar relay to just swing from side to side, closing and opening contacts. We are also concerned with the timing or precision with which it operates. For instance, a polar relay that is improperly adjusted may elongate or shorten the *mark* or *space* pulses. This is called *bias distortion* and it is a troublesome and unwelcome intruder. The elongation of the *mark* pulse, and the resultant shortening of the *space* pulse, simply means that the relay adjustment is such that the armature spends more time at the *mark* contact than it does at the *space* contact, even though the length of the pulses being fed into the relay are equal. One should be certain as to whether or not the *mark* and *space pulses* being received really are equal before an accusing finger is pointed at the polar relay. If the polar relay is in proper adjustment an elongated signal fed into it comes out elongated. Likewise, a shortened signal fed into it comes out shortened.

It can be seen, then, that one of the important reasons for adjusting the polar relay is to either eliminate bias distortion altogether or at least keep it to a minimum. Sometimes, you hope for the first and settle for the last.

At this point one might well ask why the armature of a polar relay will spend more time at one side than the other, elongating either the *mark* or *space* pulse. It is generally considered that the polar relay is "spring-less" since it has no spring to hold or bias the amature to one side. The construction of the armature is such that it *does* have some allowable spring action in its long slender length since its base end is rigidly anchored. Incidentally, the contact spring sections (two pieces) at the free moving end of the armature are of non-magnetic spring material to cushion the contact action at this point. Under proper adjusted conditions, the distance of travel of the end of the armature, at the two contact points, is only 0.002 inch each way from center (0.004 inch total travel distance). This certainly is not much movement and it is several inches from the rigid end of the armature. Nevertheless, it requires spring action on the part of the armature. If the adjustable contacts and the adjustable pole pieces are screwed back a ways the armature stands free. In the proper adjustment of the relay the idea is to advance the adjustable pole pieces and adjustable contacts up to but not quite touching the armature. One can readily see that the armature action can be easily distorted if the adjustable contact and pole pieces on one side are advanced further than those on the other side. In fact, since the armature moves so easily it is possible to shove it over considerably to one side or the other without realizing it. Result bias distortion. This simply means that in pushing the armature to one side, the short flat spring section of the armature has been distorted, giving tension (or mechanical bias) to the armature. This, in turn, introduces the bias distortion. There are other adjustments associated with the armature that can assist in eliminating or reducing bias distortion and these will be covered later.

Polar Relay Test Set

It would be most desirable to have some device to aid one in adjusting a polar relay for minimum bias distortion at a price that one could afford. You can wish for an I-193-A Test Set and if you are real lucky you might even locate a used one. With this test set you can not only set the internal bias of a polar relay to zero but you can also correct for proper sensitivity. While you are wishing for the I-193-A Test Set you may want to go ahead and build a test set similar to the one shown in figs. 5.15 and 5.16. It will be noted from the circuit diagram, fig. 5.17, that it follows closely the circuit previously published in *CQ*.[14] The author built the unit in two parts as shown. One part is simply a polar relay socket properly mounted, with a four foot cord to plug into the other unit. The second unit houses the meter, resistors, capacitors and power supply. The

[14]RTTY Column, Byron H. Kretzman, *CQ*, November, 1960, p. 111.

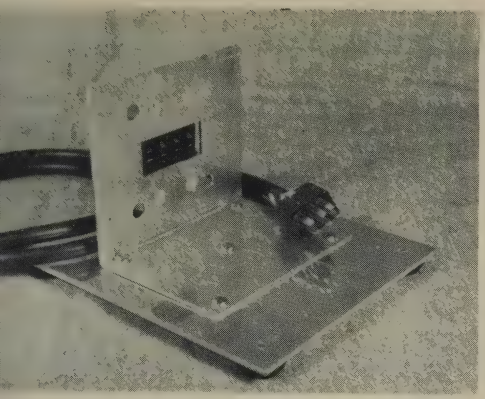


Fig. 5.16—Close-up view of the polar relay test socket. The large base flange prevents the relay from tipping over the base.

power supply was not included in the original circuit, but there were a number of advantages that made the addition worthwhile.

In the first place, a polar relay should not be tested and adjusted on an operating table where it will be near the receiver, transmitter, or other ham shack gear as well as any tools or other metal objects that might exert any appreciable magnetic influence. One shouldn't overlook the fact that this also includes the test set's own power supply as well as the meter. Meters, as a rule, have very strong permanent magnets so they can be the worst offenders if they are in the vicinity of the relay under test. The polar relay being tested should be at least two feet from such objects in order to be sure that they are not exercising any magnetic influence. The author used a four foot cord to be doubly sure. The four foot lead also adds to the flexibility of the test set since the two foot requirement eliminates most of the operating tables found in the average ham shack. They don't usually have this much free space. This means that the testing has to be done elsewhere such as in the shop, on the wife's kitchen table, or on the floor, away from a convenient source of 110-130 v.d.c. One shouldn't overlook the fact that the price of a few feet of twin-lead to the nearest source of 110-130 volts d.c. is insignificant compared to the price of an extra power supply.

It will be noted that a 1:1 isolation transformer was used in the power supply. One can omit this transformer and reduce the power supply cost considerably. If this is omitted it would be desirable to break both sides of the a.c. power source with the On-Off switch, and at the same time be aware of the danger of being connected directly to the line. The necessity of isolating the power supply from the vicinity of the polar relay under test is no longer a requirement if the transformer is eliminated. This naturally assumes that a choke is not added.

Under these circumstances the entire circuitry and equipment (except the meter) can be put into one cabinet and the polar relay can be plugged into one of the vertical faces. The only external component would be the meter on a four foot lead. The contents of the box would be relatively light whereas the polar relay weighs about 1½ pounds. The weight of the relay would probably cause the socket plate to tilt forward unless it was supplied with an extended base plate such as shown. The advantages of the test set being portable and completely self-contained are also obvious.

A 1-0-1 milliammeter was not available so a 500-0-500 microammeter was purchased in order to have more sensitivity. Naturally, greater sensitivity is obtained with the shunt switch, S_1, open. It turned out that even the 500-0-500

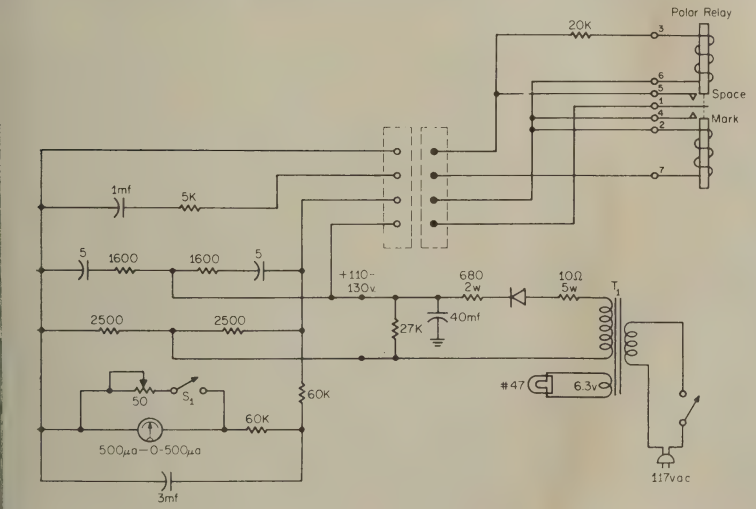


Fig. 5.17 — Circuit of the polar relay test set. Transformer T_1 is a 1:1 isolation unit. All resistors are ½ watt, 1% tolerance except for the 680 ohm and 27K in the power supply.

microammeter did not give the desired sensitivity. With a shunt, as indicated, it is possible to make initial adjustments, and then open the switch for greater sensitivity. However, if one does not use a meter more sensitive than the 500-0-500 microammeter it is not necessary to have the meter shunt and associated switch. The actual operation and use of this polar relay test set is relatively simple. The hard part comes when you begin to adjust the polar relay.

The armature (contact 1) of a polar relay plugged into this test set moves to and from contacts 4 and 5 at a frequency of about 23 c p.s., which is about the baud rate (45.45) of the amateur teletype code rate of 60 words per minute. With a properly adjusted polar relay the armature should divide its time evenly between contacts 4 and 5. Under this condition the microammeter should read zero. If the armature spends more time at contact 4 than it does at contact 5, during each cycle, then the *mark* signal is elongated (space shortened) and *mark* bias distortion is present and the microammeter will swing to one side. The distance the meter swings to one side depends upon the amount of bias distortion present.

If the armature spends more time at contact 5 than it does at contact 4, during each cycle, then the *space* signal is elongated (*mark* shortened) and *space* bias distortion is present and the microammeter swings to the other side. The microammeter and other circuitry is polarized so that a swing of the meter to the right indicates *mark* bias distortion and a swing of the meter to the left indicates *space* bias distortion. However, this is not too important as the object is to adjust the relay so that bias distortion is eliminated.

Mechanical Adjustments

The first step in the process of adjusting a polar relay is to loosen the knurled tension nut on each of the two adjustable pole pieces and back the adjustable pole pieces away from the armature just about as far as they will go. They exert their minimum pull on the armature in this position. Next, the two adjustable contacts (nos. 4 and 5) should be backed away from the armature about 1/16" to ⅛". During this latter operation one should note if each of the two contact screw brackets fit snugly around its associated contact screw. If they don't, then the screw contacts should be removed and the jaws of the contact screw bracket pressed together with a pair of pliers. The contact screws should fit tight enough in the screw brackets such that they will stay fixed during the normal operation of the relay. While the contact screws and the adjustable pole pieces are backed away from the armature it will give it a chance to swing free. Determine if the armature, in its free swinging position, is exactly centered in the oval slot in the forward end of the coil support, as well as the oval slot in the rear end coil support.

The coil can be moved about horizontally, within limits, after loosening the several screws supporting the coil spool. These screws should be well tightened after adjustment if it is found necessary to horizontally center the coil spool ends about the armature.

The armature may be slipped out to be inspected and cleaned by loosening the two armature heel piece holding screws that clamp the rear end of the armature. (See fig. 5.5) This adjustment provides for centering the front contact points of the relay, as well as vertically positioning the armature in the center of the coil spool. If it is necessary to center the contacts then the contact at each side should be advanced to within about 1/16" of the armature in order to better visually inspect this adjustment. If the contacts are not fully aligned they will not properly match or mesh with each other when they close. For instance, if the armature protrudes forward too much this puts the armature contacts out past the side contacts (nos. 4 and 5) such that they may only partially mesh or miss altogether when the relay operates. It might be necessary to go back and reposition the coil if it is necessary to loosen the armature and move it about to reposition the relay contacts. We have not been talking about the actual contact spacing, that comes next.

Contact Cleaning

The contacts should be cleaned by using a burnishing tool that has first been dipped in carbon tetrachloride. Do not touch the flat burnishing part of the tool with your fingers. Chances are that your fingers will be oily or otherwise contaminated. If you don't have a burnishing tool a flat hard surfaced clean piece of paper is better than nothing at all. A thin flat piece of metal, such as a blade of a feeler gauge can be pressed into service as a burnishing tool in the absence of anything better. Whatever is used should be free of rust, dirt, oil or other contamination and it should be thoroughly cleaned with carbon tet.

Contact Spacing

An ohmmeter should then be connected across contacts 1 and 4 (right hand contact). A 0.002 inch thick feeler gauge should be placed between contacts 1 and 4, being careful that the surfaces of the feeler gauge are parallel to the contact surfaces. The gauge should be thoroughly cleaned of all foreign material before it is used. Slowly advance contact number 4 towards the armature by turning the capstan screw with a non-magnetic tool. Such a tool

can be made from a four inch long brass rod whose diameter is about twice the hole size. Grind about a ¾ inch length at one end to fit the relay capstan screws. It was made more versatile by bending the ground-down end at about a 45 degree angle.

Try to hold the thickness gauge against the number 4 contact as it is advanced towards the armature (contact no. 1). If the feeler gauge is held against contact 1 the armature could be moved away from contact 4. Contact 4 should be advanced just up to the point where the ohmmeter shows continuity.

Contact 5 on the opposite side (left) of the armature should be advanced using the same procedures as outlined for contact 4. After this is done, check these two adjustments by carefully placing a 0.004 inch feeler gauge between the contacts on one side or the other. *Do not force the* gauge between the contacts if it does not enter readily. If it fails to fit between the contacts it means that you probably pushed the armature over slightly on one or both of the above contact adjustments. On the other hand, if the 0.004 inch gauge should fit between the contacts too readily, it means that either one or both of your intended 0.002 inch spacings are a bit more than that. It is helpful to use the ohmmeter for a continuity check in making this overall final check on the contact points. In either case, if the 0.004 inch feeler gauge fits too tightly or too loosely the 0.002 inch spacings for contacts number 4 and 5 should be done over.

After the contact spacing requirements have been satisfied the contacts should not be touched again during this general overall adjustment of the relay and we are now ready to tackle the adjustable pole pieces—one at a time.

Pole Piece Adjustment

The two knurled tension nuts, associated with the adjustable pole pieces, should first be tightened slightly before one attempts to adjust the two pole pieces. This tension should be just enough to firmly hold the pole piece as it is being adjusted. The tension should be increased slightly with the advancement of the pole piece to its final resting position. If this is not done the pole piece will invariably shift when you finally tighten up the knurled tension nut.

Again, place the ohmmeter across contacts 1 and 4. Advance the opposite adjustable pole piece (the one that is to the left side of the armature) very carefully and slowly. As the left hand pole piece is advanced towards the armature it reaches a point at which the armature is attracted towards this pole piece, pulling the armature contact to contact 5 (on the left hand side). This is not what you are looking for at this moment. Continue to advance the left hand adjustable pole piece towards the armature until it physically touches it and further advancement of the pole piece physically pushes the armature to the right side making contact with the right hand contact (no. 4) as indicated by continuity on the ohmmeter. Do not advance the pole piece past this point—just to the point of contact. Now back off the pole piece about one half of a turn (more or less). When this is done the armature naturally follows the left hand pole piece back until the armature contact rests on the left hand contact (no. 5). The half turn back up of the pole piece was sufficient to still leave a small air gap between it and the armature with the armature contact resting against the left hand contact (no. 5).

At this point you may leave the ohmmeter connected across contacts 1 and 4 or else place it across numbers 1 and 5. Better still, if you have two ohmmeters place the second one across contact numbers 1 and 5. Advance the right hand adjustable pole piece towards the armature, fast at first, then slowly as it approaches the spacing of the other pole piece. At some point in this area the pull on the armature from the advancing right hand pole piece exceeds the pull from the left hand pole piece. When this happens the armature contact (no. 1) breaks continuity with the left hand contact (no. 5) as indicated by the associated ohmmeter. The armature may swing on across and make contact with the right hand contact (no. 4) as indicated by the ohmmeter at the right hand side, or it may assume some neutral position in between contacts 4 and 5 depending upon how skillful you were in your adjustments and upon the condition of your particular polar relay.

If your work was done well a visual inspection should indicate that the space between the armature and the adjustable pole pieces on either side is about the same and more important the armature stands midway between the contact points. Also, the armature will stick lightly against whichever contact it is moved to by means of a gentle push with a slender tooth pick. It may be necessary to readjust the first pole piece ever so slightly or maybe both before your adjusted polar relay passes the "tooth pick and sticking" test. If it passes this test chances are that the microammeter pointer will be resting squarely on zero when you plug the relay into the polar relay test set. If it is not on zero, one or the other, or possibly both pole pieces, will have to be moved ever so slightly to cause the meter to read zero. You can now finish tightening the two knurled tension nuts. Be sure to hold each pole piece capstan firmly in position with its adjusting tool while the tension nut is being tightened or else it will also turn and all will have to be done over.

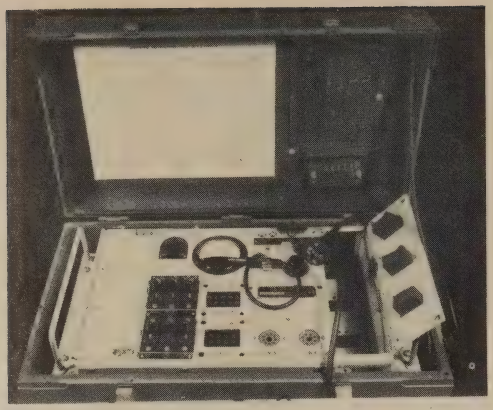


Fig. 5.18—TheI-193-CWestern Electric Polar Relay Test Set.

The I-193-C Western Electric Polar Relay Test Set shown in fig. 5.18 was used to verify the adjustments on a number of polar relays. It proved that one does not necessarily have to have an I-193-C Polar Relay Test Set to satisfactorily adjust a polar relay.

Mercury Relays

Another type of relay that is finding favor in RTTY circles is the mercury-wetted contact relay, particularly the Western Electric types 275 and 276. It gets its name from the fact that its contacts are continuously coated with mercury. The contacts are sealed in a glass enclosure that is hydrogen filled and the contacts are solenoid operated. The Western Electric mercury relays are encased in a metal tube shell with an octal base and it is desirable that these relays be mounted in a vertical position.

Mercury relays were not manufactured with RTTY in mind. Their uses are many-fold; likewise, their design varies considerably. For instance, the resistance of their coil (or coils) vary all of the way from a few ohms to several thousand ohms. Naturally, the coil current requirement also varies over wide limits. Generally, it is necessary to operate the relays at a current considerably higher than their listed value. In fact, some have found it necessary to increase the operate current to several times the listed value. The RTTY beginner would probably find it a rather confusing and baffling chore to select a mercury relay in the face of so many types and models and varying operating specifications. You also take them "as is" since they are sealed and are not adjustable.

At a 60 w.p.m. keying rate, there is a short period of time during which all of the relay switching contacts are electrically connected. This time should be no more than one millisecond for the W.E. type 275 or 276.

The Florida RTTY Bulletin, (put out by W4RWM) has published data on the Mercury-Wetted Contact relays from time to time and has indicated (January, 1965 issue) that if you find a mercury-wetted relay and don't know what it is, send the number to the Florida RTTY Bulletin and they will furnish the specifications.

Solid-State Relays

Solid-state switching was covered extensively in the discussion of f.s.k. Some of our readers have no doubt wondered, as they read the discussions on the mechanical polar relay, why one should not abandon, or why the RTTY'ers haven't already abandoned, the mechanical polar relay altogether in favor of solid-state devices. Precedent or established practices probably account for a great number of RTTY'ers sticking to the tried and time tested mechanical polar relay. There are more proven circuits around using these polar relays and, of course, by no means least is the relatively low cost and general availability of the mechanical polar relay. Then too, solid-state relays as well as mechanical polar relays, also have definite drawbacks. It will be recalled that teletypewriter selector magnet coils and polar relay coils require a d.c. voltage in the order of 120 volts or more while the voltage for transistors range more in the 3 to 50 volt range.

Model 538-A Relay

A number of solid-state relays are being produced commercially. One company producing a line of solid-state relays is the Trepac Corporation of America.[15] In fact, one of their relays, the Model 538-A transistorized high speed telegraph relay is a replacement for the Western Electric 255-A polar relay and its terminal pin base arrangement is the same. This makes it possible to remove the 255-A relay and plug the 538-A relay directly into the socket. This assumes that the 255-A relay socket was correctly connected, in the first place, in accordance with standard polar relay pin terminal designations which are as follows:

Signal Line Positive—Pin No. 3
Signal Line Negative—Pin No. 6
Bias Supply Positive—Pin No. 7
Bias Supply Negative—Pin No. 2
Mark Contact—Pin No. 4
Tongue Contact—Pin No. 1
Space Contact—Pin No. 5

A general view of the 538-A relay is shown in fig. 5.19 and a top view of the relay case is shown in fig. 5.20. A general schematic of the relay is shown in fig. 5.21. It will be noted that

[15]30 West Hamilton Avenue, Englewood, New Jersey.

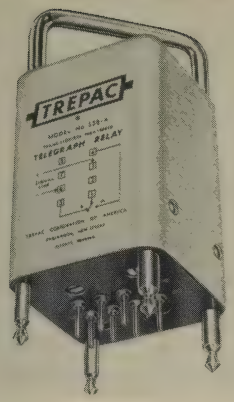


Fig. 5.19—The Trepac 538-A transistorized high speed telegraph relay. The unit is a direct replacement for the W.E. 255-A.

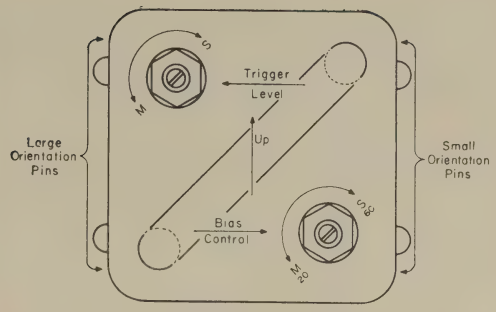


Fig. 5.20—Top view of the Trepac 538-A telegraph relay showing the location of the BIAS and TRIGGER LEVEL adjustments.

the 538-A is *not* fully a solid-state relay. It is a modern design approach to the relay problem which uses the best characteristics of both solid-state and mercury-wetted devices. The manufacturer states that there is no operation which can be performed in the switched output of the type W.E. 255-A polar relay which cannot be performed *better* by the Trepac 538-A relay.

The input circuit to the 538-A is purely resistive. There is no interaction between units connected in the same signal loop, and no inductive kick can be reflected into the signal line to interfere with other equipment or change transmission line characteristics. Any number of 538-A relays can be placed in series or parallel so long as the current requirements are met. The 538-A relay will operate satisfactorily from a neutral or polar signal input over a wide range of line currents (approximately 8 to 140 ma or greater if required). Full data on the 538-A is given in the table of fig. 5.22 supplied by the manufacturer. It represents average measurements made on a number of production units with the BIAS CONTROL set to 0 bias output with a square wave input.

The resistive input impedance of the 538-A may be reduced approximately 50 percent as shown on right side of table, if operation is with signal line currents of 25 ma or more. Since many teleprinter circuits operate on 60 ma loop current the 538-A is shipped with a 300 ohm wire-wound resistor connected from terminal 3 to 6 within the base of the unit. This resistor may be disconnected for lower current operation by removing and insulating the lug attached to one end of this resistor. The input circuit is provided with a 0.175 amp fuse in the positive lead to input terminal 3 within the relay base recess. The input circuit will withstand severe overloading (up to 200 milliamperes) without damage to the unit. Continuous operation at this current will open the fuse installed at the factory.

The output circuit is a transistor-driven high speed mercury-wetted contact capsule which provides complete electrical isolation between the input and output circuits together with high

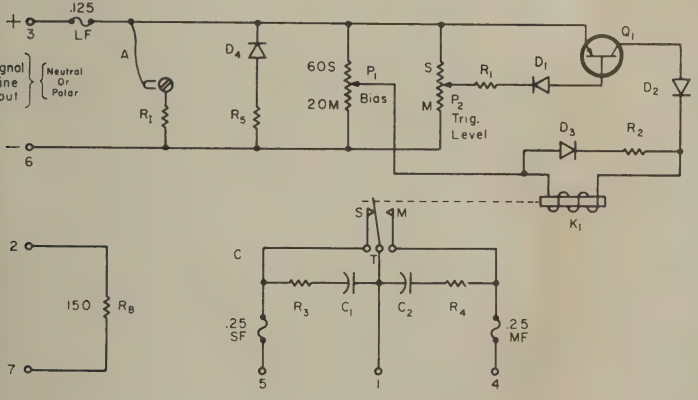


Fig. 5.21—Circuit of the Trepac 538-A telegraph relay. Fuse marked LF is for the line, SF-*space* and MF-*Mark*. Resistor R_I is the internal shunt and R_B is the bias resistor discussed in the text. Jumper *A* is removed for all neutral and polar signals from 8 to 18 ma. Tongue (Contact 1) is in contact with the *space* (5) terminal with no signal or with a negative signal to terminal 3. Applied signal closes 1 and 4. Relay K_1 is a high speed mercury wetted contact unit.

Input Sig. Line ma	E_{meas} across #3 and #6 (*volts*)		Calculated Impedance (*ohms*)	
	With No Ext. Shunt	With 300 Ω Ext. Shunt	With No Ext. Shunt	With 300 Ω Ext. Shunt
8*	2.1	†	263	†
10*	3.2	†	320	†
15*	7.8	†	520	†
20	3.2	†	160	†
25	4.6	2.3	184	92
30	6.0	3.0	200	100
40	8.4	4.8	210	120
50	11.0	5.8	220	116
60	13.4	7.2	223	120
70	16.0	8.4	228	120
80	18.0	9.8	225	122
90	21.0	11.1	233	123
100	23.0	12.4	230	124
120	27.8	14.6	225	122
140	28.0	17.0	200	121

*Internal 300 ohm shunt not used.
†External 300 ohm shunt not used.

Fig. 5.22—The current and input resistance characteristics of the Trepac 538-A relay are shown above.

voltage and high current handling capabilities far beyond that obtainable with transistors alone. This relay has no contacts to maintain, clean, adjust, arc or pit. The steel case of the 538-A relay is grounded to all four of the corner orientation plugs, which provides complete electrical as well as magnetic shielding of the relay. For proper switching action the signal circuit positive should be applied to relay socket terminal 3 and the negative return connected to relay socket terminal 6. This is in accordance with standard polar relay pin terminal designations. It will be noted that no electrical bias supply is required for the normal operation of this relay. When this relay is plugged in the socket in place of a W.E. 255-A, the relay socket bias connections are not disturbed but have no effect on the operation of the 538-A. Actually, the 538-A relay has an internal wirewound resistor of 150 ohms that is connected to pins 2 and 7 merely to provide a normal load on the bias power supply and continuity to any other external circuit connected to these terminals at the relay socket. It will be noted from fig. 5.21 that these two terminals are not connected to anything else in the relay.

538-A Bias Control

It may be seen from the top view of the relay, shown in fig. 5.20, that there is a BIAS CONTROL whereby the *mark and space* signals may be lengthened or shortened. The manufacturer stated that tests made with the relay showed a gain of 8 points on the low end plus a gain of 5 points on the high end of the teletypewriter range was accomplished. This was an overall gain of 13 points in the receiving range of the machine.

It was pointed out in the early part of the text, under the "Range Finder" section, that a teletypewriter machine receiver mechanism was so designed that it required only 20%, or 4.4 ms of the 22 ms pulse in which to operate. It was further stated that the machine is equipped with a range finder which could be adjusted so that the machine selecting mechanism is functioning at the midpoint of the 22 ms interval. The range finder is equipped with a scale graduated from 0 to 120. A machine in good working order, will copy when the selector pointer is set anywhere in about the center one-third portion of the scale. The Trepac relay makes it possible to widen the range, or extend the margin under which the machine will continue to print properly by the aforementioned 13 points.

Distortion

Tests with 40% switching bias and end distortion were also made. In every case, the use of the Trepac Model 538-A transistorized high speed telegraph relay, provided operation superior to that obtainable from the type W.E. 255-A relay, and test results far exceeded the minimum requirements of Bell System Practices.

Switching, as referred to here, means the changing from *mark*-to-*space, or space*-to-*mark*. Bias means the elongation of one pulse (*mark* or *space*) with the consequent shortening of the other (the same amount that the other pulse was elongated). Bias distortion was discussed in connection with mechanical relays. "End distortion" is similar to bias distortion. These two types of distortion, as well as other types of RTTY distortion, will be covered in detail just a bit further along in the text.

Detailed mechanical adjustments required to eliminate or reduce bias distortion was thoroughly covered. Here is a relay that requires no contact or mechanical adjustments. In fact, there is nothing mechanical to adjust. On the other hand, it does have an electrical BIAS control that can be adjusted or changed at the will of the operator. This control is shown as P_1 in fig. 5.21.

It will be recalled that, in the discussion of the operation of the 255-A polar relay, the 2-7 terminal winding is used as a bias winding holding the armature against contact terminal 5 (*space*) and the signal voltage is applied to the 3-6 terminal winding which moves the armature to the 4 (*mark*) contact. Up to this point, we have had considerable discussion about the movement of the polar relay arma-

ture (terminal contact 1) to and from the *mark* and *space* terminal contacts 4 and 5. Nothing has been said about the transit time required for the armature to move from the *mark* contact to the *space* contact or back. Some time, however small, is involved in each instance. The Trepac Corporation of America states that this transit time is approximately 1 millisecond for their 538-A relay and is graphically illustrated in the square waves of fig. 5.23 (B), (C), (D), and (E).

The relay is factory set for a nominal 60 ma neutral signal input, polar output. The bias control is set for equal duration of both the *mark* and the *space* pulses as in keying a polar signal line with terminal 4 *mark*, terminal 1 tongue, and terminal 5 *space*.

Polar and Neutral

The amateur seldom uses a polar relay so that all contacts (1, 4, and 5) are used at the same time. Such a circuit is called a polar circuit and is used in land-line teletype circuits. If the 538-A relay output is to be neutral, that is, with the *mark* output taken from contact no. 4 *closed* to tongue no. 1, and the *space* output taken from contact no. 4 *open* to tongue no. 1, then the *space* pulse will appear longer than the *mark* pulse. This is due to the transit time of about one millisecond that it takes the tongue to move from the *mark* (4) contact to the *space* (5) contact. To compensate for this transit time and apparent spacing bias when using the 538-A relay to key a neutral output, and restore the equal *mark/space* ratio, turn the bias control slightly in the *mark* direction (towards *M*).

If the 538-A relay output is to neutral and inverted (with the *mark pulse* from terminal 5 and tongue 1) then the *mark* pulse will appear longer than the *space* or open conditions of the contacts, and to restore the 50% M/50% S ratio, the bias control should be turned slightly in the *mark* direction. (The bias control is also inverted). The Model 538-A relay will compensate for *mark* or *space* weighting in the received signal. To introduce weighting in the relay output, to increase the pulse length appearing across terminal 4, and tongue no. 1, turn the bias control towards *M*. This also reduces the pulse length appearing between terminal 5 and tongue 1. To increase the pulse length appearing across terminal 5, and tongue 1, turn the bias control towards *S*. This also reduces the pulse length appearing between terminal 4 and tongue 1.

The *mark* and *space* settings of the bias control are relative. The bias control is entirely electronic, and establishes the ratio of the *mark* and the *space* pulses appearing in the relay

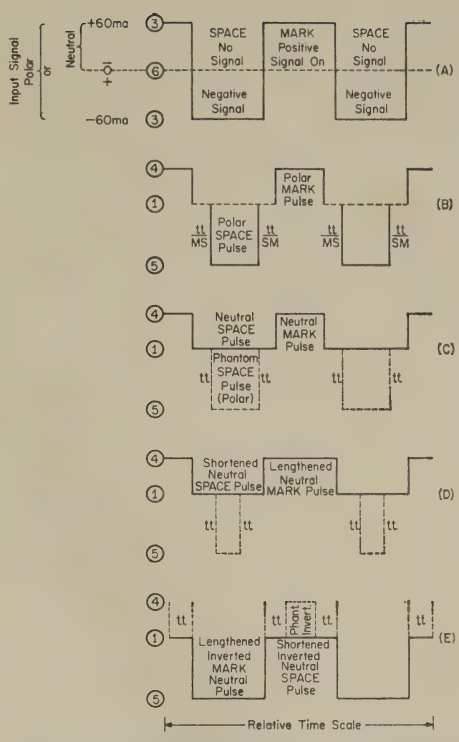


Fig. 5.23—The effect of transit time (travel of armature, contact 1) between contacts 4 and 5 (*mark* and *space*). (A) shows the input signal; 1-polar, +60 to −60 ma or 2-neutral to + 60 ma. (B) This waveform is the output with the nominal factory setting 50M/0/50S for polar output (*mark*-continuity, 4-1, *space*-continuity, 5-1). Transit time is noted as *tt*. (C) presents the apparent neutral output showing the spacing bias effective at nominal factory settings (*mark*-continuity, 4-1, no connection to 5). (D) Shows the *mark* pulse lengthened by use of the BIAS control to provide equal length *space* and *mark* pulses from the neutral output. (E) shows how the space pulse may be lengthened with the BIAS control in inverted type operation transit time, *tt*, is equal to approximately 1 millisecond.

output. When using the 538-A on a 60 ma signal line, the 50% M/50%S setting will be toward the 60 log point on the scale. Turning the bias control potentiometer toward *S* from this point, will lengthen the pulse appearing across terminals 5 and 1. Turning the bias control toward *M* from the nominal factory setting, will lengthen the pulse appearing between terminals 4 and 1. When using the 538-A on a 20 ma signal line, the potentiometer setting of the bias control will be toward the 20 end of the scale. When using the 538-A on any intermediate current signal range, the setting will be between the 20 and 60 ma points on the

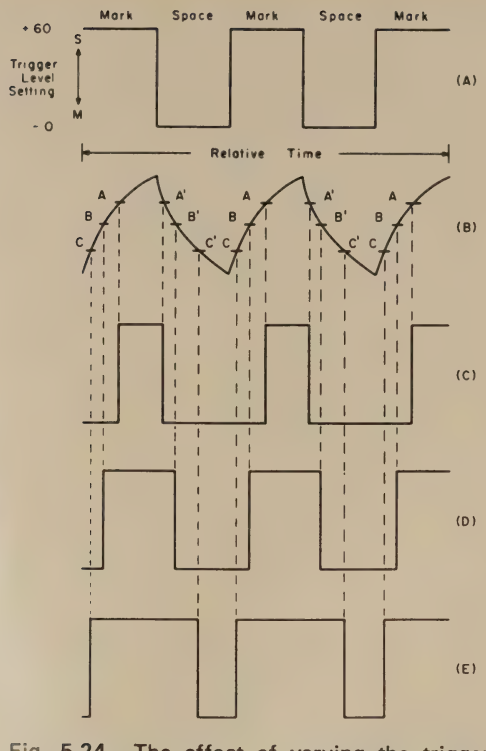


Fig. 5.24—The effect of varying the trigger level control of a 538-A relay is shown above. (A) Shows a neutral square wave signal that would be fed into a transmission line. (B) Shows that same signal at the end of a long line having suffered heavy characteristic distortion from the line capacitance and resistance. Waveforms *C, D* and *E* represent the square wave outputs from the transistor clipper that are fed to the mercury relay. Waveform (A) Shows the trigger level set too high on the current curve toward the *S* setting. This lengthens the *space* and shortens *mark*. (D) Shows TRIGGER LEVEL at the factory setting for equal *mark* and *space*. (E) Shows the TRIGGER LEVEL set too low (towards *M*) for lengthened *mark* pulses.

scale and if operation at higher signal line currents is desirable, the setting may be nearly fully clockwise beyond the 60 end of the scale.

The same procedure for setting the relay output weighting by the bias control potentiometer will apply regardless of the nominal setting for a particular signal line current.

Trigger Level Control

The relay has a TRIGGER LEVEL control which is an effective wave shaper which controls the *turn-on* and *turn-off* point of the Schmitt Trigger type of input circuit. This can also be readily observed in the circuit shown in fig. 5.21. This is particularly important in line service where a long line may have heavy *characteristic* distortion due to line capacitance and resistance. However, this control can also be important in RTTY work because the keying wave at the output of the Terminal Unit may not always be the nice square wave that we would like.

The trigger level control is set at the factory for a nominal "crossover point" of approximately 30 ma, assuming the unit will be used on a 60 ma neutral signal line or loop. Normal operation will require no further adjustment of this control. If it should be desirable to set the crossover point higher on the current curve of the signal line, adjust the TRIGGER LEVEL control slightly toward *S*. This reduces the sensitivity of the transistor input, requiring a higher input current to actuate the relay contact output. If it is desirable to set this crossover point lower on the signal line current curve, adjust the TRIGGER LEVEL counterclockwise toward *M*. This increases the sensitivity of the transistor input, requiring a lower input current to actuate the relay contact output.

If the 538-A is to be used at the end of a long neutral transmission line where characteristic distortion caused by large amounts of line capacity and resistance will tend to weight the received signal with a heavy marking bias, the trigger level control should be set higher on the current curve to cut off the "die-away tail" of the capacity discharge on the line. Turning the TRIGGER LEVEL control toward *S* enables *slicing* the signal line current curve to reestablish an equal *mark/space* ratio in the output of the Model 538-A relay.

The normal adjustment of the BIAS *control* which is set for equal *mark/space* ratio on a square-wave input signal is not disturbed and is not used for correction of this type of bias on the signal line.

If the trigger level is properly set to provide equal *mark/space* relay output from a line with heavy characteristic distortion, an increase in signal line current level will introduce marking bias, and a decrease in signal line current will introduce spacing bias, but the effect will be somewhat less noticeable than with the conventional type of relay.

The TRIGGER LEVEL control can be used to set the turn-on and turn-off points of the 538-A relay to within a few milliamperes of each other. If the input signal is a reasonably square wave, the trigger level control can be set in each of a number of 538-A relays operating in the same series or parallel loop, to turn on and off at different signal levels without interfering with each other or distorting the output pulses. This provides a convenient and accurate means of obtaining multi-level signaling. A supervisory or monitor signal current of 5, 10, or 20 milliamperes (or other current levels)

can be in the signal line at all times, without triggering the units set to respond only to higher current levels. The effect of varying the trigger level control of the 538-A relay is graphically or pictorially shown in fig. 5.24.

The Trepac Model 538-A is extremely rugged, and will hold its adjustment indefinitely. As the units may be tumbled about, the mercury pool in the contact capsule may flow down and short the contacts. Prior to insertion of the Model 538-A relay in the relay socket which has previously been checked out, suspend the 538-A relay from its handle, and give the side of the case a sharp rap with the knuckles. This will cause the excess mercury on the capsule contacts to return to the mercury pool, and normal relay operation will be obtained when inserted in the socket.

Other Trepac Relays

Trepac manufactures numerous other relays and other solid state devices for teletypewriter and other telecommunication services. The 538-A model relay just covered probably has more direct interest or appeal to the amateur since it is a direct replacement for the W.E. 255-A. The Trepac 538-B/2, a replacement for the Automatic Electric PTW 202-A polar relay, is electronically identical to the 538-A but equipped with a banana plug base. The Trepac Model 538-A/O, a replacement for any octal based polar relay such as the Sigma 72, is also electronically identical to the 538-A except that it is equipped with an octal plug base. If you wish to use a Trepac relay but are not replacing a 255-A relay, it might be simpler to select a 538-B/2 (with banana plug base) or a 538-A/O (with an octal plug base) unless you just happen to have a 255-A socket lying around. The octal base plug for the 538-A/O is shown in fig. 5.25. Additional data on Trepac relays may be obtained from K4MUB.[16]

Bias Distortion

Bias distortion does not originate only in polar relays. There are other sources of this type of distortion in the RTTY system. However, bias distortion from the polar relay is probably the easiest to track down and correct.

The discussion of bias distortion, as covered sometime back, was centered around the polar relay. It was discussed there as a "byproduct" of a mechanical misalignment of the polar relay. It is considered that a review or discussion of the nature of bias distortion is in order since bias distortion is not restricted to just the polar relay. In fact, it is almost a constant and unwelcome companion of the RTTY'er.

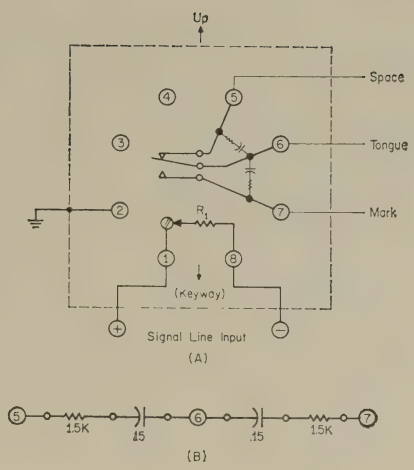


Fig. 5.25—(A) Bottom view of the octal base plug of the Trepac 538-A/O relay. (B) These components may be added externally across contacts 5, 6 and 7 to compensate for inductive loads greater than 75 ma and 130 volts.

Consider a simple square wave. If such a wave is passed through a half-wave rectifier then a wave form such as that shown in fig. 5.26(a) is obtained. This is a pulsed wave with equal periods of signal and no signal. Consider the periods of signal as *mark* and the periods of no signal as *space*, with all periods, whether *mark* or *space*, being equal. This represents a signal with *no bias* distortion.

Figure 5.26(b) is simply an expanded view of one cycle for better viewing clarity. Let us suppose that *mark* and *space* are no longer equal as in (b) but 25% *marking bias* is present as illustrated in (c). In this case, *mark* is 25% longer and *space* is 25% shorter. This condition exists because the *space-to-mark* transition is 25% *early*. Let us suppose that 25% *spacing bias* is present as illustrated in (d). In this case, *space* is 25% longer and *mark* is 25% shorter. This condition exists because the *space-to-mark transition* is 25% *late*.

A simple on-off or reversal type of signal was used in the examples of fig. 5.26 in order to keep things simple and as uninvolved as possible. The important thing here was to show the reader that the fundamental mechanics of bias distortion are actually pretty simple. Before we leave the subject of the nature of bias distortion it might be well for us to go through the whole process covered in fig. 5.26 with an actual teletype code character. The character "R" was selected since it has already been under discussion in this series. This is shown in

[16]Hal A. Trenner, Trepac Corporation of America, 30 West Hamilton Avenue, Englewood, New Jersey.

fig. 5.27. If there is any difficulty understanding fig. 5.27, refer back to fig. 5.26 again. Do not go on to *end distortion* which is covered next if you are still having difficulty with bias distortion. There is a similarity between the two that gives the uninitiated a bit of difficulty in distinguishing one from the other and remembering which is which.

Let us go back for another look at the teletype code character "R" which is reproduced as (a) of fig. 5.27. Figure 5.27(b) shows 25% marking bias for "R" and fig. 5.27(c) shows 25% spacing bias. It will be noticed that with 25% marking bias distortion that the signal transition from *space*-to-*mark* is 5½ milliseconds *early* and that the transition from *space*-to-*mark* is 5½ milliseconds *late* with 25% spacing bias.

End Distortion

If the term *"bias distortion"* sounded strange to the beginner, then the term *"end distortion"* probably sounds more strange. The beginner usually has some difficulty with these two types of teletype distortion because of their similarity. It may appear at first that they are essentially one and the same. Bias distortion is encountered in the *space-to-mark* transition of a signal and *end distortion* is encountered in the *mark*-to-*space* transition of a signal.

Consider the signal of fig. 5.28 (a) in which the *mark* and *space* segments of the square wave pulses are of equal length as in fig. 5.26 (a). Figure 5.28 (b), as in fig. 5.26 (b), is simply an expanded view of one cycle for better viewing clarity. Let us suppose that *mark* and *space* are no longer equal as in (b) and that 25% *marking end distortion* is present as indicated in (c). In this case, *mark* is 25% longer and *space is* 25% shorter. This condition exists because the *mark*-to-*space* transition is 25% *late*. Let us suppose that 25% *spacing end distortion is present as illustrated in* (d).

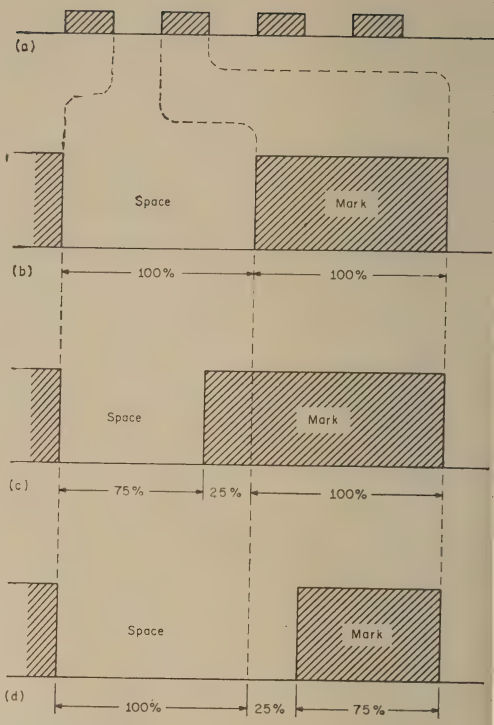


Fig. 5.26—(A) The periods of signal and no signal (*mark* and *space*) are all equal. (B) shows one cycle expanded for clarity. (C) shows the actual configuration if 25% marking bias is present and (D) if 25% spacing bias is present.

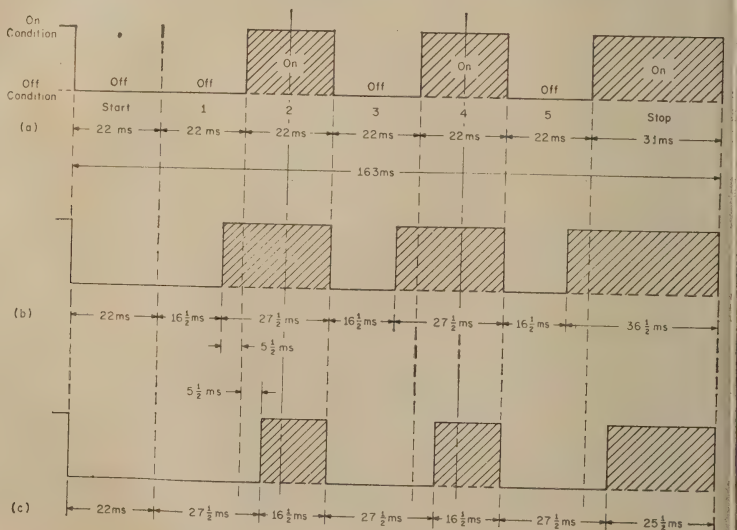


Fig. 5.27—(A) is the Teletype code for the character *R* with no bias distortion present. (B) indicates the presence of 25% marking bias distortion and (C) indicates presence of 25% spacing bias distortion.

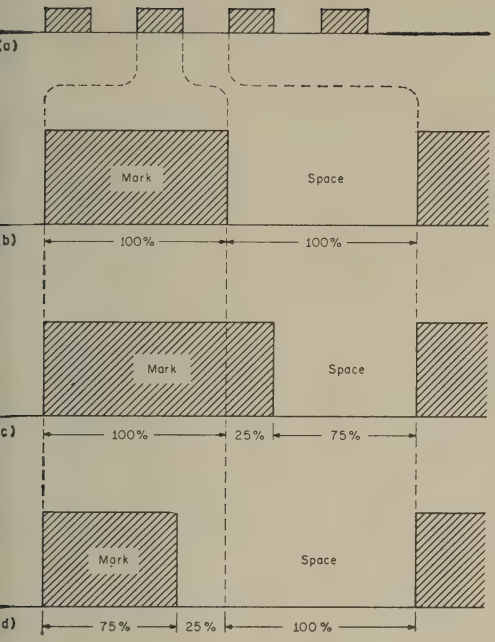


Fig. 5.28—(A) and (B) indicate signal and no signal (*mark* and *space*) all equal. (C) represents 25% marking end distortion and (D) 25% spacing end distortion.

In this case, *mark* is 25% shorter and *space* is 25% longer. This condition exists because the *mark*-to-*space* transition is 25% *early*.

A simple on-off type of signal was used in fig. 5.28 to explain end distortion as was used in fig. 5.26 to explain bias distortion. Figures 5.26 and 5.28 should be thoroughly compared to see the difference between these two types of distortion. Figure 5.29, using the teletype code character "R", is used to further explain end distortion. The teletype code character "R" with no end distortion (or any other distortion) is shown in (a). Figure 5.29 (b) shows the character "R" with 25% marking end distortion and fig. 5.29 (c) shows 25% spacing end distortion for the letter "R". It will be noticed that with 25% marking end distortion the signal transition from *mark*-to-*space* is 5½ *milliseconds late* and that the signal from *mark*-to-*space* is 5½ milliseconds *early* with 25% spacing end distortion.

One may be prone to question any real difference between bias distortion and end distortion, since one occurs on the front end of the *mark* pulse while the other occurs at the other end of the *mark pulse*. Perhaps the simplest answer is that early experimenters seemed to think that there was a difference between the two and accordingly differentiated between them. One is just about as troublesome as the other since they both affect the *mark* pulse which reminds one that the selector magnet operates, or actually moves on the presence of a pulse (mark) and not on the absence of a pulse (space).

Fortuitous Distortion

The *space*-to-*mark* and *mark*-to-*space* transitions are displaced by fortuitous distortion in a random fashion, shortening both the *mark* and *space* pulses. One source or cause of fortuitous distortion is the teletypewriter keyboard. Its cause and correction will be covered later on in this text.

There are other sources of fortuitous distortion such as sudden fluctuations of the local loop voltage. The use of regulated power supplies is very helpful. There are still other

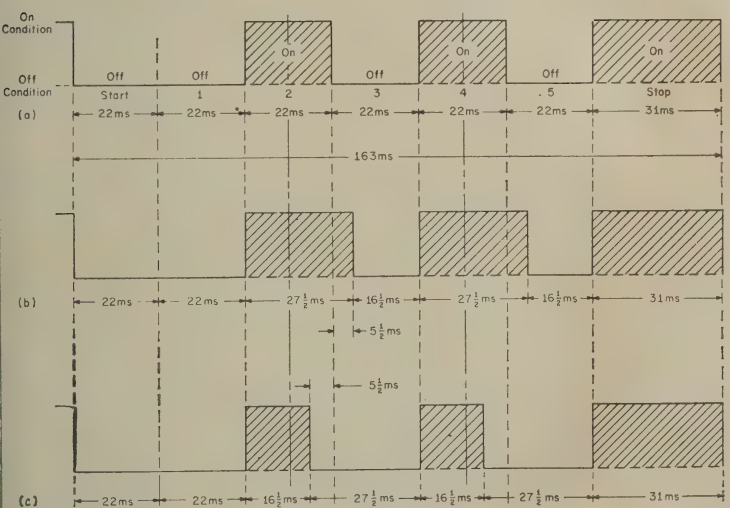


Fig. 5.29—(A) is the Teletype code for the letter *R* with no distortion present. (B) shows the introduction of 25% marking end distortion and (C) shows 25% spacing end distortion.

sources of fortuitous distortion. One of the worst, besides the keyboard transmitter contacts, is caused by multipath travel of a radio signal from the transmitting station to the receiving station.

Characteristic Distortion

One knows that where there is only resistance in a circuit a waveshape is principally attenuated but not altered. When capicitance or inductance enter into a circuit the wave may be altered—enter characteristic distortion. This type of distortion was briefly mentioned in connection with the Trepac semi-solid state 538-A polar relay sometime back.

The very nature of a teletype code depends upon the closing and opening of circuits in transmitting the "intelligence" to a teletype machine. The closing and opening of an energized circuit containing resistance only can result in a square current wave such as shown in fig. 5.30 (a). Consider the case of closing an energized circuit where inductance is present. This causes the current to build up from zero to its maximum value with a slight delay as graphically shown by the sloping part of the curve on the front side of the signal of fig. 5.30 (b). The presence of the inductance in the circuit keeps the current from dropping to zero the instant that the circuit is opened. This is graphically shown in the "trailing" effect on the end of the

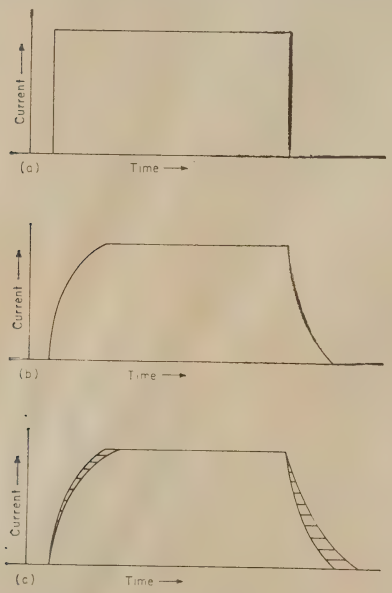


Fig. 5.30—(A) This perfect square wave is developed by opening and closing an energized circuit that contains only resistance. (B) is the resulting waveshape if the circuit also contains inductance. The effect of the addition of capacitance in the circuit is shown in (C).

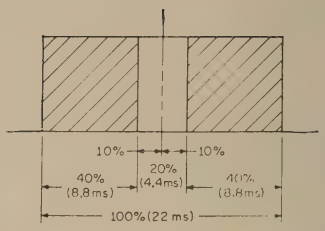


Fig. 5.31—The selector magnet functions during the 4.4. ms time segment in the center of the 22 ms signal pulse.

pulse of fig. 5.30 (b). The presence of capacitance in the circuit causes further shaping of the rising (front) slope and of the decaying (rear) slope of the wave as shown in fig. 5.30 (c). Additional inductance and capacitance further shapes the wave as indicated in fig. 5.24. One can begin to appreciate the value of the "trigger control" on the Trepac 538-A relay just covered, and its function which was graphically illustrated in fig. 5.24.

Characteristic distortion can cause the shortening or lengthening of a single *mark pulse* when it follows two or more *space* pulses. The reverse is true for a *space* pulse. The amateur RTTY'er is not concerned with long lines and inevitable characteristic distortion but he is concerned with such devices as filters. In fact, filters are the "life blood" of one's Terminal Unit. Everyone knows that a filter is made up of inductances and capacitors. In fact, a good sharp filter is loaded with both and it certainly is no surprise that characteristic distortion appears when we get to filters. With polar relays it was bias distortion to combat. Now we find that with filters that it's characteristic distortion that we come to grips with.

The practical effect of characteristic distortion in filters is that the *mark* pulse, for instance, that is expected at a filter output, is dependent upon the pulses that preceded it as well as their polarity (*mark* or *space*).

40% Margin Of Distortion

It was stated earlier that a teletype machine selector magnet functions during 4.4 ms of the 22 ms allocated for each element of the five level code. It was further stated that it was desirable that the 4.4 ms period be located in the center of the 22 ms segment. This was graphically illustrated for the teletype character "Y" in fig. 3.3, and also indicated in fig. 5.31. It will be noted that 4.4 ms is 20% of 22 ms. If this 20% segment of time is located in the center of the 22 ms segment, it leaves a 40% time segment or 8.8 ms on either side as shown. This means that the selector magnet of a teletypewriter machine can not theoretically

accept more than 40% bias or end distortion without making errors in copy. This assumes, of course, that the range finder of the teletype machine is properly adjusted so that the 4.4 ms time segment during which the selector magnet functions is centered in the 22 ms time allocated for the associated signal pulse. It might appear, to the uninitiated, that a 40% margin of distortion is so great that one does not need to be unduly concerned with distortion. This comfortable margin in allowable distortion, before errors of copy begin to appear, can in actual practice disappear all too soon.

In the first place, the receiving teletype machine may start making errors at a figure lower than 40%. This can be due to lack of proper adjustment of the machine or because the operating parts cannot function properly due to an accumulation of a gummy substance composed of dirt, tar, grease, *etc.* that tends to restrict their operation. One of these is usually the case. Of course, it can be due to other things such as worn, bent or mutilated parts, springs too tight or too loose, *etc.* There is always the possibility that a particular teletype machine is so thoroughly worn that no amount of adjusting or cleaning will coax it to pass the 40% copy test. There is the possibility of distortion in both the sending and receiving process. The margin of maximum distortion can be due to the actual teletype machines themselves, as has been pointed out, to polar relays (also covered) to the Terminal Unit, or to a degradation of the signal in transit from transmitter to receiver. Whatever the cause, the cumulative effect of RTTY distortion can reach the copy error point more easily than one might think.

Distortion Conclusions

With all of the discussions of distortion in this text. one may get the idea that the RTTY'er is literally adrift in a sea of distortion without any recourse. The fear or apprehension of the unknown is usually worse than the real thing, so just knowing the exact status of a situation brings some satisfaction.

The techniques and types of equipment used to track down and measure these various types of RTTY distortion depend upon the type you are pursuing and whether or not one or more of the other types is present. Some devices either indicate or measure the *total distortion present.* For this reason, one needs to know the types of distortion present when using a device that measures total distortion. For instance, if one is trying to determine the exact amount of bias distortion present it is important to know if the figure obtained really is bias distortion or some other type.

One's thoughts naturally turn to the possibility of distortion measurements and ways and means of making such measurements. The availability of instruments to measure distortion such as encountered in amateur RTTY work is practically nil so far as the amateur is concerned. Naturally, the Bell System companies have such instruments but not in great quantities as each instrument serves quite an area or "goes a long way." This means that this source is nil. A few distortion measuring instruments are made and sold separate and apart from the Bell System. The price of these instruments is such that it places them out of the realm of practicality for most radio amateurs.

6

SPECIAL RTTY CIRCUITS

It must be pretty apparent that one must strive to rid an RTTY system of distortion even though "store-bought" RTTY distortion equipment is not at all common to the radio amateur's shack. Some very few have access to RTTY distortion measuring devices where the majority must rely mostly on time consuming and painstaking "cut and try" and eternal experimenting.

The author has devised an instrument to be used in locating, checking and measuring RTTY distortion. It is most important that first some of the circuitry that went into the design of the device be covered before the actual instrument. This point has further significance, since much of the circuitry to be covered is considered basic for the modern Terminal Unit.

Square Waves

The subject of square waves has never been of much importance or interest to the average amateur unless he happened to be an RTTY'er. Square waves are all-important to the RTTY'er and a respectable knowledge and understanding of them is an almost must. Unfortunately, most beginners in RTTY work are not too well versed in the fundamentals of square waves.

A 23 cycle per second *sine wave* is one thing and a 23 cycle per second *square wave* is an entirely different thing. The square wave is made up from a combination of many sine waves. How many sine waves are involved depends upon how "square" the square wave really is. In all instances, it is made up of first the fundamental frequency (23 c.p.s. in this case) and *odd multiples* (harmonics) of the fundamental frequency.

Square waves can be created easier than they can be analyzed. Figure 3.2 indicated how a square wave could be generated by a very simple method. Here the switch is opened and closed in a series circuit and the current pulses are square since only resistance exists in the circuit.

Figure 3.5 showed how square waves were generated by the keyboard contacts in a direct wire hookup. Here, the resistance of the circuit is kept high compared to the inductance of the selector magnets in order to maintain good square wave characteristics.

Another simple means of creating a square wave is indicated in fig. 6.1 and its transistor counterpart is shown in fig. 6.2. These are actually simple switching circuits that switch a voltage and current on and off. In the circuit shown in fig. 6.1, the switch is actuated man-

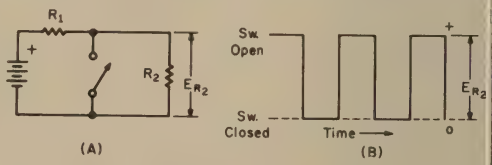


Fig. 6.1—Shown above is a simple switching circuit (a) that creates a pulsating d.c. square wave (b).

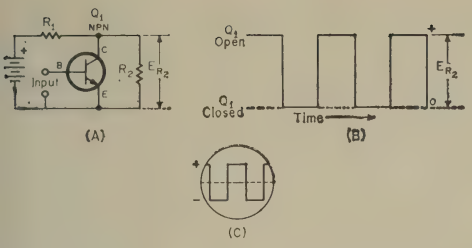


Fig. 6.2—The simple transistor switching circuit (A) creates the pulsating d.c. square wave shown in (B). When viewed on most oscilloscopes this wave form appears as an a.c. signal shown in (c).

ually. In the circuit of fig. 6.2, the transistorized version, the switch is Q_1 and can be actuated electrically. In both circuits the output waveform is a pulsating d.c., the output rising from zero to some positive value and then back to zero.

It must be realized that the simple on-off d.c. signal produced by the circuits of figs. 6.1 and 6.2 turn out to be square waves with positive and negative half-cycles when reproduced as a trace on a scope that does not use direct-coupled amplifiers to its vertical deflection plates. This fact should be kept in mind when working with signals and circuits similar to these.

The transistor Q^1 in fig. 6.2(A) can be considered as replacing the manual switch in fig. 6.1(A). The emitter current controls the transistor resistance between emitter and collector. This resistance is very high when there is no emitter current flowing and it drops to a very low value (almost a short circuit) when the emitter current is high. The emitter current is determined by the emitter-base junction bias as applied to the input of fig. 6.2(a). Maximum current flows when the emitter-base junction is heavily forward-biased (plus to the base). Additional forward biasing of the transistor does not increase the emitter-to-collector current. In fact, a point could be reached where the emitter-base junction could be burned out by too much forward-bias voltage.

Reverse-bias (negative voltage to the base) to the emitter-base junction produces the opposite effect. Reverse bias cuts off the emitter-to-collector current. By going from a no current condition to a maximum current condition we have, in effect, a switching transistor that has two states—cut-off or saturation (off or on).

A vacuum tube keyer circuit, given in fig. 6.3, is another form of switching circuit. It will be noted that this circuit is similar to the keyer portion (V_5 and V_6) of the W2JAV converter circuit shown in fig. 4.6. Various

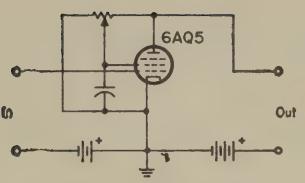


Fig. 6.3—Simplified circuit of a vacuum tube keyer.

versions of this circuit are in wide use by RTTY'ers. The tube bias and screen voltage are adjusted so that the plate current is at approximately the cut-off value with no signal input. A strong square wave input signal gives a pulsating direct current square wave signal at the tube output.

In each instance, in fig. 6.1 and 6.2, note that the square wave was formed by the voltage rising from a zero value (switch closed) to its full value E_{R2} (switch open). It maintains the E_{R2} value until the switch is closed and then it immediately drops to zero. It is interesting to note that in the very beginning of an RTTY signal, which starts at the keyboard transmitter contacts, the signal created is a square wave such as just described. Note further that this *pulsating direct current* signal becomes a square wave *alternating current* signal when it passes through other than a direct-coupled amplifier stage (to be covered in a moment). Note finally that this originally pulsating direct current RTTY signal after taking on various forms in the radio transmitter, through space, through the receiver and finally through the converter or terminal unit, emerges (if it makes it) as a pulsating direct current signal that operates our teletype printer. For that reason, it pays good dividends for any RTTY'er to learn all he can about square waves.

Square Wave Analysis

A sine wave, when added with its third harmonic, is shown in fig. 6.4. Note how closely the resultant resembles a square wave. As the 5th, 7th, 9th *etc.* harmonics are added

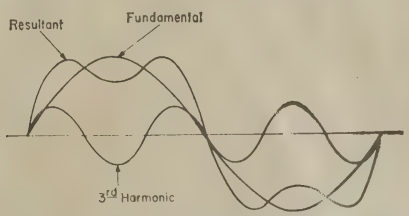


Fig. 6.4—The fundamental sine wave plus the third harmonic produces a resultant close to that of a square wave. Additional odd harmonics bring the resultant closer to a perfect square wave.

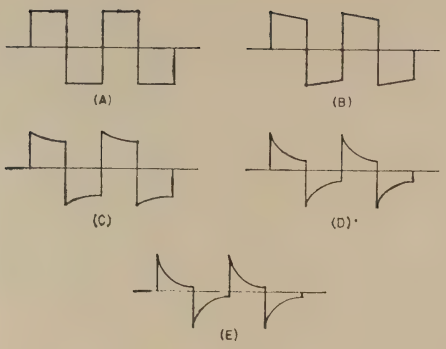


Fig. 6.5—The various scope traces from (b) to (e) are each due to a different frequency response and phase relationship in an amplifier as discussed in the text. The input in each case was the perfect square wave shown in (a).

the resultant becomes closer to a perfect square wave. A good square wave is one that contains the odd harmonics up through the 21st harmonic. Each harmonic must have the proper amplitude and the proper phase with regard to the fundamental signal. If either the amplitude or the phase of one or more harmonics is changed the square wave shape is altered.

Amplifier Response

The frequency response and phase shift in the internal amplifiers of a scope affect the trace of a square wave shown on the scope tube face. Some are shown in fig. 6.5. Actually, the various traces shown in fig. 6.5 can be the result of the frequency response and phase shift in any amplifier whether it be a part of an oscilloscope or some other device such as a speech amplifier or a part of an RTTY *terminal unit.*

Traces (b)(c)(d) and (e) are only intended as a general guide, since any circuit causing frequency amplitude variations (poor frequency response) and phase shift can give a varying response, depending upon the amount of each present. Distortion of the bottom and top of a square wave (a curved line instead of a straight line) is an indication of a lack of perfect low frequency response. A tilt of the top and bottom of a square wave is an indication of a phase shift. A tilt downward (from left to right) of the plus cycle indicates a phase shift *decreasing with frequency.* This could be caused by a grid-coupling capacitor that is too low in value. If the top of the wave tilts in the other direction it is an indication of phase shift *increasing* with frequency.

Trace (a) shows an undistorted square wave. Trace (b) shows practically no very low frequency drop and practically no rise at extremely high frequencies and the overall frequency response is flat with a small phase shift decreasing with frequency.

Trace (c) shows a little more phase shift and the effect of a decreasing frequency response at the low end although the overall frequency response is fairly flat. Trace (d) shows some phase shift, a peak in the high frequency response and a fairly sharp low frequency cutoff while the overall frequency response is not so flat. Trace (e) shows phase shift, a very definite low frequency cutoff as well as a pronounced high frequency peak with the overall frequency response anything but flat.

Conclusions

One of the handiest pieces of electronic test equipment to have around, next to the v.o.m., is an oscilloscope. An RTTY'er, like the phone man, can hardly operate his station without an oscilloscope. Generally speaking, an RTTY'er needs a better quality scope. The reason for this is that the RTTY'er is mostly concerned with square waves. Further, the RTTY'er is principally interested in a square wave of 23 c.p.s.

It is most desirable that the scope has a frequency response that will permit the trace shown in (a) fig. 6.5. One can settle for a trace such as (b) or even (c) in a scope. Let us suppose that our scope produces trace (c) for an input wave such as (a). When a square wave such as (a) is put through an amplifier that is under test and if the amplifier has a very good frequency response, the signal will appear as trace (c) since that is the response of our scope for a perfect square wave. If the amplifier under test has poor low frequency response if may appear as a trace such as (d) or (e). In this case we have to compensate mentally, for the scope deficiencies by comparing traces (c) and (d) or traces (c) and (e). From this, it can be seen that the testing of an amplifier for its square wave response can become somewhat sticky if the scope that we are using to make the test isn't flat either. If the scope response is poor, our job becomes progressively more difficult.

Special Circuits

The distortion test set, previously mentioned, as well as the Terminal Unit, and many other Terminal Unit designs collectively use numerous circuits not too common to amateur radio except for RTTY work. For that reason, it is considered appropriate that some of this circuitry should be touched upon at this time before going into the actual design and circuitry of the special distortion test set, which uses

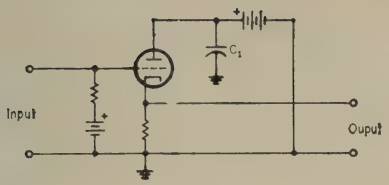


Fig. 6.6—A basic cathode follower circuit.

some of this circuitry. All of the circuits to be covered are somewhat inter-related and some of them are referred to by more than one name which can be confuse.

The further one gets into the study of RTTY, especially Terminal Units, the more he begins to wonder if he is still on the RTTY subject or somehow got switched to the subject of computers. One begins to read about Eccles-Jordan circuits, flip-flops, triggers, logic, schmitt trigger, *etc.* The modern Terminal Unit uses numerous circuits that are quite common to computers. In addition, there are such terms as "decision circuits," point at which a circuit "changes state," and decision threshold computer circuits, as well as others that will be covered in due course.

The Cathode Follower

For many years the load of a vacuum tube was placed in the plate circuit of the tube and this was commonly known as plate loading. About the time of World War II another method of loading a vacuum came into existence. This new method was called *cathode loading* and an amplifier stage with cathode loading was called a *cathode follower.* The basic circuit of a cathode follower is shown in fig. 6.6.

The voltage gain of this stage is always less than one since the output voltage is always less than the input voltage. Since such a stage does not have a voltage gain, one is prone to question as to what useful purpose it might serve.

Distortion in a cathode follower is usually low because of the 100% negative voltage feedback inherent in such a stage. An additional value of a cathode follower is in its impedance characteristics. The input impedance is high and the output impedance is low, which makes it quite useful and practical as a driver for Class AB_2 and Class B amplifiers. One is familiar with the 180 degree phase shift between the input voltage and output voltage of a plate-loaded amplifier. The input (grid) and output (cathode) voltage of a cathode follower are *in* phase. This feature as well as the low output impedance of a cathode follower makes it particularly useful where pulse techniques are involved such as in RTTY work. Also, the cathode follower can provide current gain. (This means power gain, too.)

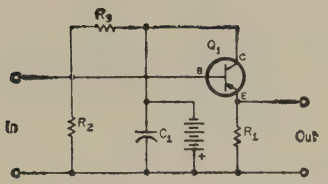


Fig. 6.7—The basic circuit of the common collector amplifier, the transistorized equivalent of the cathode follower.

This discussion of a cathode follower would not be complete without reference to its transistor counterpart, the *common collector* amplifier. Figure 6.7 gives a basic circuit schematic of a transistor common collector amplifier or emitter follower as it is sometimes called. Capacitor C_1 is for bypassing the collector to ground. Like the cathode follower, the emitter follower has a voltage gain of less than one. The main reasons for its use are the same as those for the cathode follower, high input resistance and very low output resistance as well as a good current gain. The common collector amplifier is sometimes called an *emmitter-follower* since the voltage drop across the emitter resistor tends to follow the input voltage to the base. This is similar to the way the voltage drop across the cathode resistor of a cathode follower follows its grid voltage.

Direct-Coupled Amplifiers

Obtaining uniform frequency response or any response at all in an audio amplifier becomes more difficult as the frequency approaches zero or near zero. Some of the effects of poor frequency response in audio amplifiers at extremely low frequencies were just discussed. The use of a transformer becomes less practical both technically and economically at very low frequencies. Even with resistance-capacitance coupled stages a limit is reached as the operating frequency approaches zero.

A practical solution to this problem is to use *direct-coupled amplifiers* which are sometimes called direct-current amplifiers since they will amplify down to d.c. A direct-coupled amplifier will amplify low frequencies, uniformly and without phase shift or attenuation,

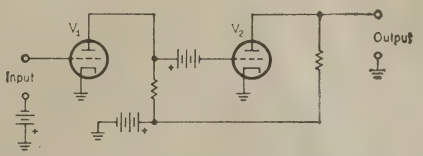


Fig. 6.8—Simplified schematic of a direct-coupled amplifier. Such an amplifier will handle low frequencies down to d.c. without phase shift or loss of response.

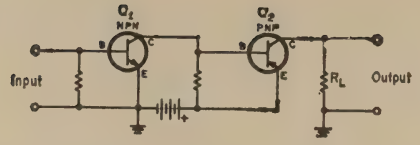


Fig. 6.9—A direct coupled transistorized amplifier is shown above. The use of both an n.p.n. and p.n.p. type simplifies the problems as explained in the text.

right down to zero. After the seemingly insurmountable problems associated with low frequency response, especially at RTTY frequencies, one can readily see that such an amplifier would be bound to find favor in RTTY applications.

An elementary circuit of a direct-coupled amplifier using tubes is shown in fig. 6.8 and a circuit using transistors is shown in fig 6.9. These circuits are basic for the sake of simplicity. Actual working circuits are found in varying forms depending on design requirements.

When vacuum tubes are cascaded in a direct coupled circuit, voltages become a problem as may be seen in fig. 6.8. In this form two separate voltage sources are used. In another form one source of voltage is used but it must be greater in value (at least the sum of the two individual voltages).

In the transistorized version shown in fig. 6.9, the use of a p.n.p. and n.p.n. transistor permits a single voltage source to be used that is no greater than usual (about 9 volts).

The collector of Q_1 in fig. 6.9 requires a positive voltage. The emitter of Q_2 requires a positive potential since the collector of Q_2 is returned to ground through the output load R_L. The biasing arrangement, as shown in fig. 6.9 makes it possible for the collector of Q_1 to be connected directly to the base of Q_2.

Glow Lamps

The neon glow lamp or neon bulb, as it is so commonly referred to, has been with us for a long time. Radio frequency ammeters and other r.f. indicating devices have always been expensive and as a result, the use of a neon bulb as a favorite r.f. indicator has been pretty universal. For some, this is perhaps the extent of their knowledge of the neon glow lamp although it has quite a number of other uses in electronics.

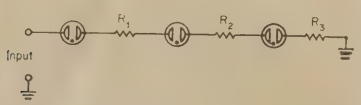


Fig. 6.10—The use of neon glow lamps as voltage indicating devices, are shown above.

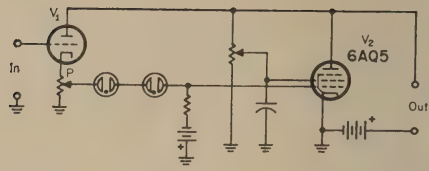


Fig. 6.11—A basic keyer circuit combining details previously described as explained in the text.

The actual goings on in a neon glow lamp are quite complicated and beyond the scope of this text. In this instance, we are more concerned as to *what* happens than we are with *how* it happens. The thing that interests us at the moment is that the neon glow lamp offers a *high resistance* in a series circuit when the lamp is *non-conducting* and that this lamp offers a *low resistance* in the series circuit after the lamp "fires" and is in a *conducting* state. As the voltage across such a lamp is increased, a value is reached at which the lamp fires and becomes conducting. This voltage is called the *breakdown* or *firing voltage*.

It is possible to design glow lamps for a wide range of currents and initial breakdown voltages. However, the most common currents encountered in commercial lamps range from about 0.1 milliampere to 10 milliamperes. The initial breakdown voltages generally encountered range from 55 to 150 volts and the maintaining voltages usually range from 50 to 80 volts. Discharge lamps such as the neon glow lamp must be equipped with a current limiting series resistor, called a ballast resistor, to prevent instantaneous burnout. The applied voltage, series ballast resistance and other circuit resistance determines the current, light output and life of the lamp.

Voltage Level Detectors

The frequency response of a neon glow lamp to normal RTTY audio frequencies is essentially flat. The glow lamp is a very good visual RTTY signal indicating device. It blinks and glows in unison with the RTTY signal. The glow lamp is also a very good voltage level indicating device. The range may be extended by connecting a number of lamps in series as shown in fig. 6.10. The resistors R_1, R_2 and R_3 are the ballast resistors that are usually placed in the base of the lamps. When the voltage to the input reaches up to the sum of the firing voltages of the three lamps, the lamps fire giving a visual indication that the pre-determined voltage level has been reached. If the voltage is a direct current source the lamps glow with a fixed glow. If the voltage is an a.c. or pulsating voltage, then the glow from the lamps pulsate on and off accordingly in unison with the voltage.

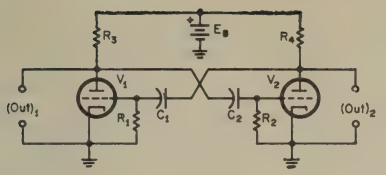


Fig. 6.12—Basic circuit of an astable multivibrator better known as a free-running multivibrator.

Another use for the neon glow lamp is indicated in fig. 6.11. The lamps in this circuit are, in effect, a special type of voltage level indicating device and perform an additional function as well. A vacuum tube keyer circuit was given in fig. 6.3, a cathode follower circuit was given in fig. 6.6 and a direct-coupled amplifier circuit was given in fig. 6.8. It will be noted that fig. 6.11 is a combination of all three with fig. 6.10 also thrown in. The combination of all four of these basic circuits into the circuit of fig. 6.11 gives a very useful device that is well known and much used in RTTY circles. In fig. 6.11 tube V_1 is a cathode follower. The coupling of V_1 to V_2 by means of the glow lamps gives us a special kind of direct-coupled amplifier. The 6AQ5, V_2 is a keyer tube whose bias, screen and plate voltages are adjusted such that the plate current is cut off when there is no signal to V_1. When the cathode voltage of V_1 at point P to ground increases to the value necessary to fire the neon bulbs, this positive voltage is suddenly applied to the grid of V_2 offsetting its negative grid bias voltage. This condition causes V_2 to suddenly conduct and the tube draws a fairly high plate current. This is a basic terminal unit keying circuit that, with modifications, is used by many RTTY'ers.

Multivibrators

The multivibrator is another circuit that has been around for a long time. For the most part, it was associated with frequency measuring devices for many years. The rapid strides taken since World War II in the development and use of computers has given new emphasis to multivibrator circuits. In fact, the multivibrator has become the work-horse for digital computers. As a result, many configurations of this all-important circuit have been developed. A number of them are just as important to RTTY work. Two triodes, either vacuum tubes or transistors, make up a multivibrator. First one triode conducts then the other one conducts (alternately).

Multivibrators may be divided into three basic types, *astable, monostable* and *bistable*. The basis for these three classifications is the *number of stable end states* associated with each. All three types have definite and valuable applications so they will be covered individually.

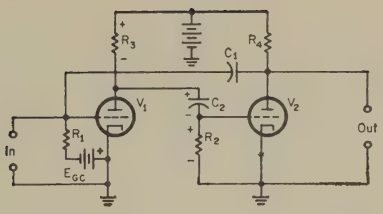


Fig. 6.13—Basic circuit of a monostable multivibrator also known as the one-shot multivibrator.

Astable Multivibrators

The astable multivibrator gets its name from the fact that it is a free-running or oscillating device and has no *stable state*. Since it has no stable state, it switches from one to the other (oscillates). Such a device requires no input signal unless it is desirable to stabilize or synchronize its operation at a specific frequency. A circuit of an astable multivibrator is shown in fig. 6.12. This is a plate-coupled type of circuit. The transistor equivalent would be a collector-coupled circuit. Another type circuit is the cathode-coupled (the transistor type being the emitter-coupled circuit). It will be noted that the circuit has two outputs which are identical, except for a 180 degree phase difference; the output may be taken from either. The frequency of oscillation is determined by the component values C_1, C_2 and R_1, R_2. Circuit oscillations are sustained because the output of each stage is connected to the input of the other, giving both amplification and *regenerative feedback*. The waveform of the output signal may or may not be square, depending upon the selection of circuit component values. Usually a small amount of distortion is inevitably present even though the wave shape may essentially be rectangular or square. Such an oscillator is often used as a pulse generator to test digital circuitry. Such an oscillator is also a source of a square or near square wave source to test RTTY circuits.

Monostable Multivibrator

The monostable multivibrator is not an oscillator since it has one stable state. The other state is quasi-stable. In the stable state, one tube is conducting and the other tube is cut off such as in the monostable multivibrator circuit shown in fig. 6.13. The bias voltage, E_{GG}, is chosen so that V_1 is at plate current cutoff. The grid of V_2 becomes slightly positive because of the charge current of C_2 from the power supply voltage applied through plate resistor R_3, and so V_2 conducts drawing saturation plate current. This action is graphically

illustrated by the plus and minus signs as shown at plate resistor R_3, grid resistor R_2 and capacitor C_2. When power is first applied, capacitor C_2 starts charging through resistors R_3 and R_2 creating the positive bias to V_2 as shown.

When an external positive pulse is applied to the input of V_1 and it exceeds the negative bias voltage, E_{GC}, it suddenly causes V_1 to conduct and V_2 is at current cutoff due to regenerative feedback. In other words, the circuit changes state so that V_1 now conducts and V_2 is nonconducting; V_2 is biased negatively, far beyond cutoff, by the discharge current of C_2 during this quasi-stable period. Eventually the negative charge on the grid of V_2 dissipates to the point where V_2 starts conducting and the state reverses back to what it was originally (V_1 at cutoff and V_2 conducting).

This phenomenon just described is why the monostable multivibrator is often called the "one-shot" multivibrator. The length of the output pulse, during the quasi-stable period, is determined by the circuit time constant.

From the preceding discussion it is seen that triggering a monostable multivibrator causes it to change state and then revert back to the stable state that existed before the triggering signal was applied. It should also be noted that the monostable multivibrator is triggered only by a positive signal and a negative signal has no effect on the grid of V_1. If the triggering pulse is applied to the grid of V_2 this condition is reversed. It would take a *negative* pulse to trigger V_2.

A monostable multivibrator is useful in restoring or regenerating pulses that have become distorted.

Bistable Multivibrator

The astable and the monostable multivibrators, just covered, both have their applications in RTTY work. They lead us to still another type of multivibrator, the bistable multivibrator. This one is more commonly encountered in RTTY work.

The bistable multivibrator is known by a number of other names, the most popular of which is the *flip-flop*. It is also called the start-stop multivibrator, as well as the *Eccles-Jordan Trigger Circuit*. A typical circuit is shown in fig. 6.14.

Note that the circuit of fig. 6.14 is symmetrical and so is the circuit for the astable, or oscillating multivibrator, shown in fig. 6.12. This naturally leads to the question as to why one oscillates and the other one does not. Furthermore, one may be prone to question why both tubes would not conduct

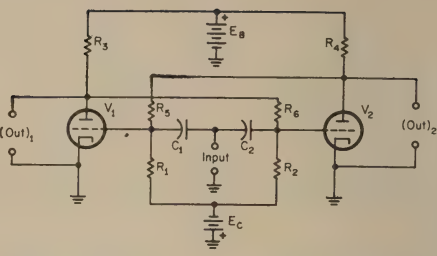


Fig. 6.14—Basic circuit of the bistable multivibrator also known as the flip-flop or Eccles Jordan.

equally well the instant that plate voltage is applied instead of one ending up conducting and the other one non-conducting. Fortunately, what may appear as being identical—tubes, resistors, capacitors, *etc.* in each half of the symmetrical circuit do not actually turn out that way in practice, so invariably, one tube will conduct more than the other one which results in the circuit flipping to a state where one tube conducts and the other one is cut off.

The bistable, like the astable, is basically a two stage voltage amplifier in which the output of each amplifier is connected to the input of the other. A characteristic of this circuit (astable or bistable) is that a plate current *increase* in one tube results in plate current *decrease* in the other tube. Regeneration is present in each circuit that results in a quick switching action the instant that power is applied. The plate current of one tube rises rapidly to *saturation* and the plate current of the other moves just as rapidly to *cutoff*. The similarity of the two circuits ends here as the astable keeps changing state (oscillating) whereas the bistable will rest indefinitely in the end state until such a time that it is triggered from an external source of signal. Two basic circuit differences account for this. First, capacitors provide for the regenerative coupling in the astable, whereas resistors are used to couple the bistable stage. Furthermore, the grid resistors of the astable circuit go directly to ground but in the bistable they connect to a source of negative grid bias. These differences keep the bistable from free-running.

The bistable multivibrator, as the name implies, has two states, being stable in either state. Like the monostable multivibrator, one tube conducts alone while the other is non-conducting. The circuit doesn't oscillate and requires an *external signal* to make it "flip" or change state. It remains in this state until the next pulse applied to its input again flips the circuit. This time it is flipped back to its original state. Unlike the monostable multi-

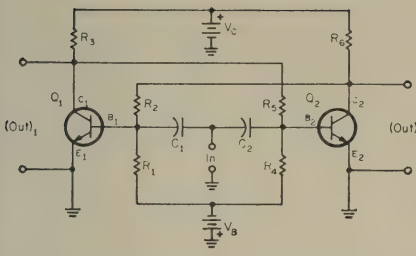


Fig. 6.15—A transistorized version of the Eccles Jordan flip-flop bistable multivibrator.

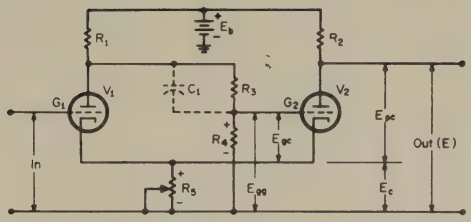


Fig. 6.16—A typical Schmitt trigger circuit.

vibrator, it will *stay* in *either state indefinitely* until it is again flipped by an external triggering pulse applied to its input.

In computer language this circuit is referred to as a *logical flip-flop*. It is considered that the first input triggering pulse *flips* the circuit *state* and the next such pulse *flops* the *state* of the circuit back to its initial state. Thus the name *flip-flop*.

This circuit can be considered to have *storage capacity*, since it will remain in either of its *stable states* until triggered from an external signal source. Let us analyze the circuit of fig. 6.14. The grid-to-ground voltage at grid of V_1 is the algebraic sum of the voltages resulting from the two voltage sources E_B (plate) voltage) and E_C (grid bias voltage). Likewise for the grid of V_2. Voltage E_B, resistors R_4, R_5, R_1, and voltage E_C form a series circuit combination that is a voltage divider for the grid of V_1. Likewise, voltage E_B, resistors R_3, R_6, R_2, and voltage E_C form a series circuit combination that is a voltage divider for the grid of V_2. The values of these resistive circuit components, as well as the circuit voltage sources E_B and E_C, are so chosen that the grid to ground voltage varies from a negative value, that will alternately drive the tubes well past their plate current cut off point, to a positive value that will alternately drive the grids into conduction.

Let us assume that tube V_1, in the circuit of fig. 6.14, is conducting. The plate voltage of V_1 is low due to the drop across R_3. This *low* positive voltage is connected to the grid of V_2 through R_6. The negative bias voltage, E_C is also connected and results in V_2 being at plate current cutoff. On the other hand, since V_2 is not conducting, there is no voltage drop across resistor R_4 which results in a very high positive voltage from V_1 grid to ground. This high positive grid voltage overcomes E_C and drives V_1 to plate current saturation.

A signal, either positive or negative, will cause the circuit to change state. If tube V_1 is conducting, a negative pulse will counteract the positive bias of V_1 and cause V_1 to cut off. This same negative pulse, which is also applied to the grid of V_2 has no effect on V_2, since it is already biased to cutoff.

Let us see what would have happened if we had applied a positive, instead of a negative signal. The positive signal would have no effect on the grid of V_1 since it already has a high positive bias. The positive signal would have an instantaneous effect on V_2, since it would put positive bias on the grid of V_2, causing it to conduct. From these two examples we can summarize that a *negative* signal will cause the *conducting* tube to *cut off* and a *positive* signal will cause the *cut off* tube to *conduct*.

Another way of stating this fact is that the circuit can be changed from one stable state to the other by applying a negative voltage to the grid of the *conducting tube* or by applying a *positive voltage* to the grid of the *cut off tube*.

Since the triggering signal is applied to both grids at the same time, the polarity does not matter, as has already been pointed out. However, there is one point to consider. Suppose that the selection of components and voltages is such that a tube is negatively biased considerably beyond cut off. This then requires a higher value positive pulse to start the tube conducting. Even then the circuit may only be affected by the peak part of the positive voltage. For this reason, it is generally conceded that this type of flip-flop circuit is more responsive to a negative voltage than it is to a positive voltage. For instance, a negative pulse of much lower value than the positive pulse may be sufficient to reduce the plate current of the conducting tube. This, in turn, causes its plate voltage to rise. This rising plate voltage is greater than the input voltage to the grid due to the tube gain. This positive voltage applied to the grid of the other tube (cutoff tube at the moment) drives it positive and it starts conducting. The circuit flips or "rolls" as it is sometimes called, especially in computer language. Thus it is seen that although an Eccles-Jordan flip-flop circuit will operate from either a positive or negative pulse that it is possible that it will operate on a lower amplitude negative pulse.

A transistorized version of the Eccles-Jordan flip-flop circuit is shown in fig. 6.15. The reader should note the close resemblance of

the circuit to that of fig. 6.14. The operation of the transistorized circuit is essentially the same as that of the vacuum tube circuit.

Schmitt Trigger

First, there was the astable type multivibrator, whose regenerative feedback was sufficient to make it a free-running, or oscillating type. This type switches from one state to the other in an oscillating fashion. Next there was the mono-stable type, with one stable state and one quasi-stable state, then the bi-stable type, with two stable states.

Under discussion now is the *Schmitt Trigger* circuit, which is even more important to the RTTY'er than the flip-flop bistable type. Actually the Schmitt trigger is also a bistable regenerative device, except that *its state* depends upon the input voltage *amplitude*. In fact, in some respects, the Schmitt trigger can function somewhat as a relay or switch such as covered in figs. 6.1 to 6.3, and in the associated text.

Essentially the Schmitt trigger circuit is a two-stage pulse-shaping circuit whose output has a rectangular waveform. The versatile Schmitt trigger circuit has many other applications, several of which can be combined in one two-stage circuit. The circuit is useful in squaring non-rectangular or sinusoidal waves, detection of d.c. levels, signal level shifting and wave-form restoration. A typical Schmitt trigger circuit is shown in fig. 6.16. There are other variations of this circuit, some of which will be covered in this discussion.

The question that naturally arises is, "What does a Schmitt trigger have that the others (astable, monostable and Eccles-Jordan flip-flop) do not have?" It has already been pointed out that it has some of the characteristics of a bistable multivibrator, except that is is amplitude-sensitive to the input signal. One might then reason that it is some kind of a monstable multivibrator, since it reverts back to its original state the instant that the input signal is removed.

In the monostable circuit the two stages are capacitive coupled, whereas direct coupling (through resistor R_3) is used in the Schmitt trigger circuit (fig. 6.16). Regeneration in the Schmitt trigger circuit is through the common and *unbypassed* cathode resistor R_5 *to ground*. Regeneration of the monostable circuit (fig. 6.13) is through plate-to-grid coupling capacitors C_1 and C_2. The Schmitt trigger changes state the instant a triggering pulse is applied to its input and so does the monostable.

At this point they begin to differ. The Schmitt trigger state stays changed as long as the triggering pulse is present; the monostable may be triggered by an extremely short pulse and its state stays changed for a period of time as determined by the circuit time constant. The monostable can actually be used as a time delay circuit. The switching time of a Schmitt trigger can be considered as being practically instantaneous so far as the usual RTTY applications go. Its action time is a matter of a fraction of to a few microseconds, depending upon the circuit. The purpose of the dashed capacitor C_1 (fig. 6.16) is to speed up the circuit switching action.

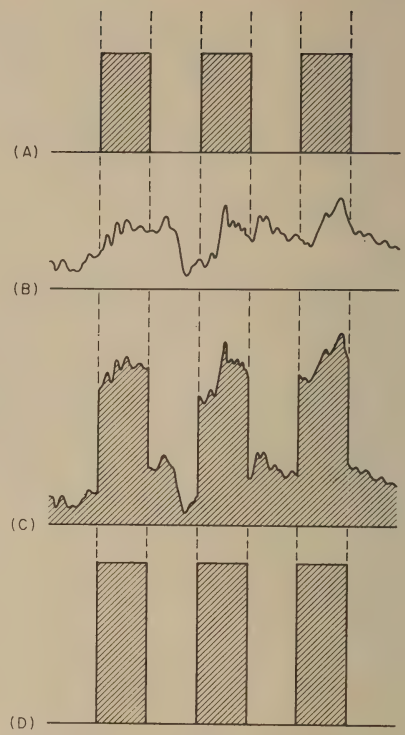


Fig. 6.17—(A) Teletype character *R;* (B) noise; (C) combination of signal (A) and noise (B) which is fed into Schmitt trigger; (D) output of Schmitt trigger. This demonstrates the use of a Schmitt trigger as a signal detector as explained in the text.

It was noted that the Eccles-Jordan flip-flop circuit, with a common input (figs. 6.14 and 6.15), operates from either a positive or negative pulse. The circuit of fig. 6.16 operates from a positive pulse but can be modified so that it requires a negative trigger pulse.

The waveform from an astable, monostable, or bistable circuit, depending upon the circuit component values selected, is generally rectangular, but not necessarily square. Quite often one top edge may be rounded and the other have a narrow but sharp "spike."

The output from a Schmitt trigger is rectangular and essentially square under almost all conditions. In fact, one of the important feature

of a Schmitt trigger is its pulse shaping and wave squaring characteristics. Regardless of the shape of a wave going in, it invariably comes out square. This is graphically illustrated in fig. 6.17. The noise, as represented in (B) is added to the teletype character "R" signal (A) which results in the distorted R signal shown in (C).

Let's review in detail exactly what took place in the Schmitt trigger circuit as graphically illustrated in fig. 6.17. Since a Schmitt trigger circuit is sensitive to the amplitude of the input signal, it is usually so designed that it will not trigger until a certain pre-determined input level is reached or exceeded. In this instance, the amplitude of teletype character R in (A) of fig. 6.17 indicates the predetermined amplitude necessary to trigger the circuit. The practical way to vary the predetermined input level is to make the cathode resistor R_5 (fig. 6.16) variable. The noise, (B), is also present at the input, along with the teletype signal (A). These two signals combine to give a resulting input signal (C). Any input signal above the pre-determined triggering level (A) saturates the input stage tube, V_1, so that the tops of the waveform (C) have no effect on the output waveform (D). Neither does the noise, graphically shown between successive signal pulses (C), affect the output wave, since none of the noise fluctuations reach up to the peak value necessary to trigger V_1. In this case the Schmitt trigger is functioning as a signal detector as well as a pulse shaping device. Obviously, the output signal (D) does not necessarily end up with the same amplitude as the input signal (A).

Let us review, in detail, the cycle of action that takes place in the circuit of fig. 6.16, although its general function may be pretty obvious. The main point is that this or any other version of the Schmitt trigger circuit *should be so designed* that it does not end up as an ordinary switch *minus* the desired regenerative *switching action*. At the instant that power is applied to the circuit of fig. 6.16 there is a tendency for both tubes, V_1 and V_2, to draw plate current even though no signal is present at the input. This current tends to build up a negative bias, E_c, for both tubes. A positive bias is applied to the grid G_2 of V_2 from the power supply voltage, E_B, through the divider formed by resistors R_1, R_3 and R_4.

This further increases the plate current of V_2, which in turn increases the negative bias (E_c) to V_1 which biases V_1 to cutoff. The voltage drop across resistor R_1 is small, since it is only due to the small current to ground through it and resistors R_3 and R_4. The positive bias to V_2 is greatest under this, the rest, or static conditions (no signal to its input), of the circuit. The net bias voltage E_{GC} to grid G_2 of tube V_2 is considerably *positive*, where V_2 is drawing

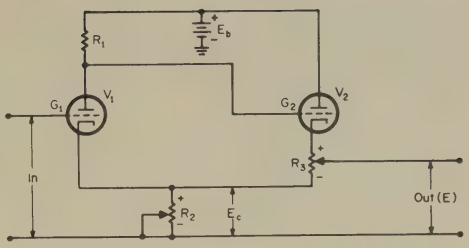


Fig. 6.18—A Schmitt trigger circuit. Note the similarity of this to the Schmitt trigger circuit shown in fig. 6.16.

maximum current and is determined from the expression:

$$E_{GC} = E_{GG} - E_C$$

Likewise, when the V_2 plate current is at its highest value, the circuit output voltage, E, is at its *lowest value* (due to the high voltage drop in resistor R_2). When an *a.c. signal* or a *positive d.c. signal* applied to the input of the circuit of fig. 6.16 equals or exceeds the predetermined triggering level of the circuit, as previously noted, the circuit will trigger. The positive signal to the grid of V_1 counteracts the static negative bias from the cathode resistor R_5 and V_1 starts to draw plate current. The instant that V_1 starts to draw plate current the voltage drop across R_1 begins to increase rapidly which in turn decreases the voltage E_{GC} and the positive bias voltage to V_2. Voltage E_C stays about the same, since the plate current of V_2 is *decreasing* at the same time that the plate current of V_1 is *increasing*.

A condition will soon be reached where the positive voltage, E_C , no longer exceeds the negative voltage, E_C. In fact, it will be less, so the net bias voltage, E_{GC}, to V_2 will be negative, as again determined from the expression:

$$E_{GC} = E_{GG} - E_C$$

Under these conditions tube V_2 is cutoff and *held* in a cutoff state so long as the triggering signal is present to keep V_1 in a *conducting state*. Under the condition of V_2 plate current cutoff there is no voltage drop in resistor R_2 so the output voltage, E, is essentially equal to the plate supply voltage E_B. If any current is drawn by a load placed at the output, this, naturally would alter the output voltage E.

From the above it is noted that the Schmitt trigger output voltage is *low* in the static (off position) and *high* in the triggered, or "on position".

Figure 6.18 shows another configuration of the Schmitt trigger circuit. The output voltage of this circuit is just the reverse to that of fig. 6.16. The output voltage is *high* in the static (off position) and *low* in the triggered or on position. The output voltage E would be zero

with V_2 at cutoff (on-position) were it not for the voltage E_c across R_2 due to the cathode current of V_1. The operation of this circuit is basically the same as that of fig. 6.16, which was explained in detail. The value of R_1 in fig. 6.16 is usually in the order of ⅓ megohm, while R_1 is in the order of 3 to 5 megohms in fig. 6.18.

7

TEST SETS

THE various types of RTTY distortion were thoroughly discussed. This should have given one a good insight into what to look for in the way of distortion, as well as some of the places and conditions under which it exists. Test sets used for adjusting and testing of the 255-A polar relay were also covered.

Need For A Bias Measuring Set

Not being able to actually measure the bias distortion in a polar relay before and after its adjustment can lead to some doubt as to the effectiveness of the adjustments in every instance. We know from practice that proper adjustments of polar relays can be accomplished with the test sets (if you have one) or even without a test set, for that matter. Yet there is nothing better than being able to check the results of adjusting your polar relay by actually measuring the bias distortion before and after.

With the above thoughts in mind, the author set out to develop some means of at least determining if bias distortion existed in polar relays other than by determining its presence by poor copy from the teletype machine. Obviously, this latter can lead to the question as to whether the polar relay, the teletype machine, or something else is responsible.

It was considered that any device or instrument developed should be simple, something that didn't take a genius a year to build and adjust, and above all, not too expensive or too sophisticated. After all, the average RTTY'er is not concerned as to whether the bias distortion from his polar relay is 8% or 8.56%. He wants to know for instance if it is 3%, 20% or maybe nothing. This kind of information (general values) can be determined from the use of a good scope and the instrument that will be discussed shortly. It was also considered that it would be an extra bonus if the simple scope measurements could be readily verified by other and more sophisticated means, if such means were available.

First Considerations

First, one must find some satisfactory way of keying the polar relay that is under test. Perhaps the first thing that comes to ones mind is a square wave audio frequency oscillator or generator capable of putting out 23 cycles per second. This is a good thought except for the fact that such audio frequency generators don't usually have enough output to drive the signal winding of a polar relay directly with the other winding properly biased. It may be possible to drive the relay directly by connecting the two windings series-aiding which is not in accordance with the conditions under which the RTTY'er usually uses the relay. Otherwise, the output from the square wave audio generator must be suitably amplified before it can drive a polar relay.

It is possible to build a square wave generator or "dot generator," as some are called, if one does not have access to a commercially built unit. The design and construction of such devices are to be found in amateur literature. One must have some means of changing the length of the individual plus halves of the signal waves, which at the same time changes the space pulses conversely. The Heathkit Model IG-82 has such a control on the chassis

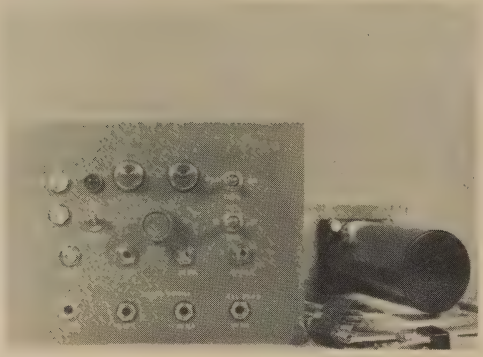


Fig. 7.1—The polar relay keyer test set is shown on the left and the external polar relay test socket and mount together with a 215A polar relay, is shown on the right. The dummy test plug may be seen just to the front of the relay. Actually, it is not necessary to panel mount both of the NE-51 bulbs as shown above. One will do nicely since they are in series and when one lights, the other will also.

designated as the signal SYMMETRY CONTROL. It is accessible only by removing the set from the cabinet. This control makes it possible to make the positive half-cycle and negative half-cycle, of the square wave, equal in length. It is also possible to lengthen the positive half-cycles, which naturally shortens the negative half-cycle. The negative half-cycle can likewise be lengthened, giving it bias.

After giving this problem some thought, it was decided to build a polar relay driver, or keyer, that duplicated as much as possible the actual conditions under which the polar relay operates when in actual use. For that reason, a part of the output keying portion of the author's Terminal Unit was duplicated in building up a polar relay keyer test set.

The Test Set

The Polar Relay Keying Test Set, designed to aid in making bias distortion measurements, is shown in figs. 7.1 and 7.2. The set was primarily designed to be used with a scope to measure polar relay bias distortion. After the test set was built, it was discovered that with a little external circuitry, bias distortion, in a Model 14 Transmitter Distributor, Model 14 Typing Reperforator, Model 15 Teletype, Model 19 Teletype machine, *etc.*, could also be measured using the set. This required no changes within the set itself and was quite an added bonus.

The design of the test set is influenced somewhat by the square wave generator used to drive it. Experience with low frequencies

Fig. 7.2—Rear view of the polar relay keyer test set, showing the general chassis layout. The plug for power cord, and plug for the externally mounted polar relay socket may be seen at the rear of the chassis.

such as 23 cycles has shown that audio transformers for oscillators and amplifiers can double or even triple the cost of such an instrument. For that reason, the manufacturers of such devices often avoid the use of audio transformers altogether. Such is the case with the Heathkit IG-82, Square Wave Signal Generator which was used by the author. The generator has a cathode follower output stage with the output voltage, with respect to ground, plus at all times. If such a voltage is applied directly to the grid of a tube such as V_{1A} through J_1 or J_2 of fig. 7.3 the grid polarity is plus with respect to ground for all of the square wave being put out by the generator. It so happens that V_{1A} *functions only from a signal on its grid that is positive* with respect to ground.

Circuit Operation

Under static conditions (no input signal) V_{1A} is cutoff and V_{1B} is conducting, the NE-51 neon lamps are glowing and keyer tubes V_2 and V_3 are in an *"on state."* A suitable *positive signal* on the grid of V_{1A} causes a plate current to flow, resulting in a very high voltage drop across the plate resistor, R_3. This, in turn, results in a very low positive voltage on the plate of V_{1A} and the grid of V_{1B}. This reduces the plate current of V_{1B} and the positive voltage drop from the arm of R_2 to ground drops too low to sustain the NE-51 lamps and they "turn off" the keyer tubes V_2 and V_3.

A less positive or a negative signal on the grid of V_{1A} causes the plate current to decrease. As the plate current through R_3 decreases, so does the voltage drop across the resistor. This allows the positive voltage on the plate of V_{1A} and the grid of V_{1B} to increase. This naturally causes the cathode current of V_{1B} to increase, which in turn in-

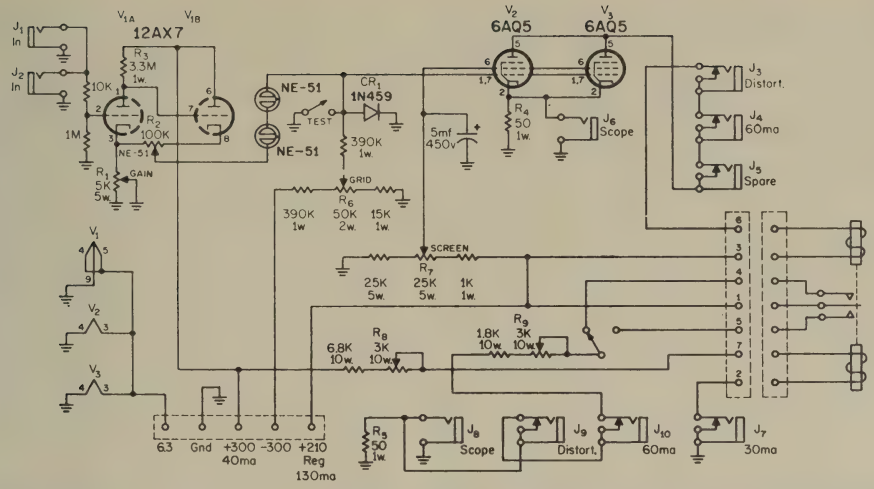


Fig. 7.3—Circuit of the polar relay keying test set. All resistors are half watt unless otherwise noted. The function of CR_1 is to provide a low resistance path when the NE-51's fire and short the grids of V_2 and V_3 to ground. The TEST switch can be a momentary push button switch or spring return toggle.

creases the positive voltage from the arm of R_2 to ground. The neon lamps will conduct when their firing voltage is reached. This positive voltage then counteracts the negative bias of keyer tubes, causing them to conduct. The plate current of the two keyer tubes instantly rises to the preadjusted value of 60 milliamperes, which operates the signal winding of the polar relay under test.

A 50 ohm resistor, R_4, was placed in the cathode circuit of the two keyer tubes, in order to monitor their action with a scope plugged into jack J_6. A 50 ohm resistor, R_5 was placed in the ground return of the keyed circuit in order to be able to monitor the keying action with a scope plugged into jack J_8.

The keyer tube output contains three jacks (J_3, J_4, and J_5). One of these jacks can be used to measure the plate current and one can be used for a distortion measuring set. A selector magnet coil of a teletypewriter can be plugged into the third jack when a properly keyed teletype signal is fed into the input of the test set. A distortion measuring set would be plugged into the tube keyer output to determine the amount of distortion, if any, present at this point. Naturally, none would be expected here if the test set is in proper working order and the input signal to the keyer test set is free of distortion.

The polar relay keyed output contains an extra output jack (J_9) for measuring any distortion in this circuit. In fact, this is the point where distortion is expected to be found if the polar relay under test is not properly adjusted. Jacks J_3 through J_{10} should be connected into the circuit with the *same polarity*, as shown, otherwise, the current would be reversed through the milliammeter that is used to check current at the various points.

It will be noted that bias distortion, or end distortion, is not measured directly by this instrument. That is the reason it is called a polar relay keyer test set, which it is, instead of a distortion measuring set. This means that there are no tedious or tricky calibrations to worry about. A scope is used to make the actual distortion measurements. The use of an external scope rather than building one into the keyer set is strongly recommended.

Scope Requirements

It takes a pretty good scope to view a 23 cycle square wave without the trace being distorted from its true form as produced by the generator. When the trace shows up on the face of the scope tube distorted, it places the operator in the position of not knowing, for sure, which to believe, the square wave generator or the scope. Naturally, this problem has to be resolved before using either instrument for further tests. Older type scopes tend to drop off in response at low audio frequencies, especially if the scope is not of the d.c. type. A d.c. type is one that has a direct coupled amplifier (covered previously) from the scope-input to the input to the vertical deflector plates of the c.r.t.

A relatively late scope, such as the Heathkit Model 10-12, has a very good low frequency audio response. Although it does not use direct coupled amplifiers, this scope responds satis-

factorily to a square wave of 23 cycles per second.

Construction

The chassis measures 2" × 5" × 7" and the front panel is 6" × 8½" × ⅛" aluminum. The general layout of the chassis is shown in the figs. 7.1 and 7.2. The power plug and the polar relay cable socket are both located on the rear wall of the chassis.

It was found convenient to have a dummy plug to fit into the relay socket. This dummy plug is wired so that terminals no. 1, 4 and 5 are shorted and a 125 ohm 1 watt resistor is connected between terminals 3 and 6 and another 125 ohm 1 watt resistor is connected between terminals 2 and 7. The dummy plug makes it possible to set all of the preliminary adjustments without subjecting a polar relay to excessive currents or other abuses. This also makes it possible to make all of the preliminary adjustments on the keyer set with only one instead of two cords plugged into the rear of the chassis while alternately turning the set on its back and up again.

Front Panel

Some of the jacks shown are insulated from the panel (jacks $J_{3,4,5,9,10}$) since they are "hot" with B+ voltage, as shown in fig. 7.3. It is highly recommended that all of the jacks, or at least the ones with high voltage on them, be mounted on a sub-panel recessed behind the main panel. Access to each jack would be through a hole in the front panel large enough for a barrel of a plug to pass through. The rear sub-panel could be bakelite or other insulating material.

Polar Relay Socket

The polar relay socket was not mounted directly on the main chassis. One might wish to inspect or make slight adjustments on the polar relay while under test and it wouldn't be easy to do this with the relay plugged into the rear of the test set. The relay socket was mounted on a special support external to the test set. It was constructed with a flexible seven conductor shielded cable, approximately four feet in length, and a suitable plug at the test set end.

Power Supply

The test set was powered with existing supplies used to operate the Terminal Units, local loops, etc. If desired, a supply could be included and some applicable circuits will be covered later. Two three hundred volt supplies are necessary, one plus and one minus with respect to ground. The plus three hundred volt supply has a 40 ma drain while the minus three hundred supply has a drain of less than a mil. The 210 volt supply must be regulated and supply approximately 130 ma.

Preliminary Adjustments

There are a few preliminary adjustments to be made before the set is ready for use. Insert a polar relay or the dummy test plug in the circuit and proceed.

The cathode feedback control, (R_1) is designated as GAIN and is located on the front panel. Potentiometers R_2 and R_6 have slotted shafts for screwdriver adjustment. They are mounted on the top of the chassis and designated respectively as NE-51 and GRID. Potentiometer R_7, designated SCREEN, also has a slotted shaft for screwdriver adjustment and is mounted on the rear flange of the chassis. These, together with the sliders on R_8 and R_9 are all "set and forget" controls.

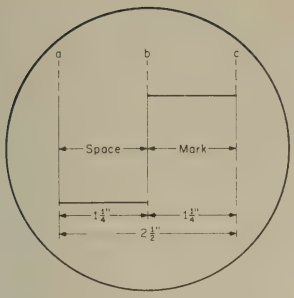
Set the slider of R_9 for 60 milliamperes through J_9 and J_{10}. Set the slider on R_8 for 30 milliamperes through J_7. The plate current (60 ma total) of keyer tubes V_2 and V_3 is determined by the screen voltage (R_7) and the plate voltage.

Close the TEST SWITCH and adjust R_7 for a plate current of 60 ma. Now open the TEST SWITCH and turn potentiometer R_2 *to zero* and adjust potentiometer R_6 so that the plate current of V_2 and V_3 is approximately zero. This gave a negative bias of —27 volts, measured from grid to ground of V_2.

Set the feedback control, R_1, with *full resistance in the circuit* which should be the *full clockwise position*. This is the setting for maximum feedback; be sure to check this with a meter.

Place a shorting plug into one of the input jacks. Bring up the level of potentiometer R_2 slightly above the point at which the two NE-51 lamps fire. Reduce the feedback control, R_1 slightly **below** the point at which the two neon lamps turn off. This is an indication that bias for V_{1A} is too low, feedback is too low, and the state of the circuit has switched with V_{1A} now conducting and V_{1B} at cutoff. If this is true there is no longer sufficient voltage from the arm of R_2 to ground to fire the neon lamps. There would be the relatively small voltage across the cathode pot, R_1, due to the plate current of V_{1A}.

If the NE-51's should start glowing again, it is an indication that some part of the circuitry has not been wired properly. If the lamps do not come back on with the test, all is in order. Now go back through the same procedures (plug shorting input and R_1 full on) and again set control R_2 slightly above the point at which the two neon lamps fire. Again, reduce the feedback gain control R_1 until the neon lamps turn off. Now turn up (increase) slightly above the point at which



g. 7.4—Scope trace of one cycle of signal in the plate circuit of the keyer tubes.

ne neon lamps again turn on.

It might be necessary, at this point, to readjust the screen grid voltage potentiometer, R_7, for 60 milliamperes of plate current. Under these load conditions, the plate voltage was 202 volts and the screen voltage was 148 volts for the 6AQ5 keyer tubes, V_2 and V_3. The no-load voltage was 214 volts for both plate and screen at the tube sockets.

The keyer is now ready for use, and none of the adjustments, except perhaps the feedback GAIN control, should require further attention. Increasing the GAIN control, R_1, up and beyond the point at which the neon lamps fire will increase the required positive input voltage necessary to trigger V_{1A}. This is desirable, under certain circumstances, and is why this control was placed on the front panel of the test set.

Operation Of The Set

The signal output from a square wave generator should be fed into one of the input jacks (J_1 or J_2) of the polar relay keyer test set. The level of the input triggering signal should be set so that the two 6AQ5 keyer tubes are keying properly as indicated by the regular flashing of the NE-51's.

At this point it might be well to call attention to the fact, by way of review, that the 6AQ5 tubes key (*mark*) on the *negative half* (less positive) of the square wave input signal and the positive half of the input wave represents *space*. If this is not clear, review the operation of V_{1A} and V_{1B} in the section on circuit operation..

The vertical input to the scope should be connected to the set through J_6, with the ground terminal of the scope connected to the sleeve of the plug. This makes it possible to monitor the keying action of the 6AQ5 keyer tubes. The scope should be adjusted so that one cycle can be observed, as in fig. 7.4. The *mark* and *space* of this signal trace should be equal if the keyer is in proper adjustment. This assumes that the positive and negative halves of the square wave input signal are equal.

If the *mark* and *space* of the scope trace are uneven, with a proper input signal, it indicates that the keyer set is not in proper adjustment. It is possible that the 6AQ5's are biased beyond plate current cut-off. The grid bias potentiometer should be readjusted while watching the trace on the scope. Any distortion present at this point will be passed on to the polar relay under test, since it is the plate current of the keyer tubes that passes through the signal winding of the polar relay. When no distortion is indicated at this point, one is now ready to check the keying action of the relay output terminals 1, 4 and 5.

Remove the scope monitor plug from J_6 and plug it into J_8. It may be necessary to readjust the scope to get a trace such as shown in fig. 7.4. Don't expect the *mark* and *space* trace to be equal unless the polar relay under test happens to be in *perfect* working order. As in the case of the test sets covered earlier, the object is to adjust the polar relay so that the *mark* and *space* on the scope trace are equal.

Amateurs usually use contacts 1 and 4 so that a closing of the contacts represents *mark* and an opening of these contacts represents *space*, with contact number 5 not being used except to reverse the action. When the action is reversed, then contact number 4 is not in use. The s.p.d.t. toggle switch on the right side of the front panel marked S and M is for reversing the action so that contacts 1 and 4 or 1 and 5 may be used. Any relay under test should be checked for each condition by operating this switch.

Determining Distortion Percentage

It will be noted that the measurements in inches of the trace on the scope were given in fig. 7.4. A special scale with percentages marked thereon could be made up and placed over the face of the scope. However, it was considered that it was as easy to use a small

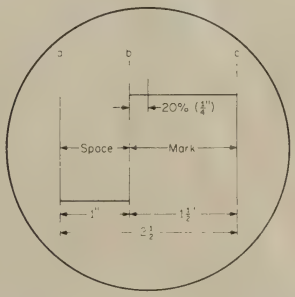


Fig. 7.5—Scope trace of one cycle of keyed signal keyed by the polar relay, showing the presence of *mark* distortion. This is indicated by the *mark* trace being longer than the *space*.

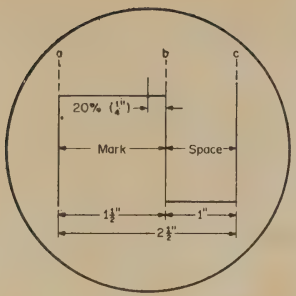


Fig. 7.6—The same scope trace shown in fig. 7.5, except the scope is adjusted so that *space* follows, instead of precedes, the *mark* pulse. The scope does not indicate if it is end distortion, as shown here, or bias distortion as shown in fig. 7.5

ruler and simple arithmetic to determine the percentage of distortion.

Let us consider that distortion is present in the keying circuit of the polar relay under test, as indicated in the trace of fig. 7.5. It will be recalled, from a study of RTTY bias and end distortion, that a longer *mark* pulse means a shorter *space* pulse or *vice versa*. The exact amount that one or the other is lengthened is the same amount that the other pulse is shortened.

The trace of one cycle (one *space* and one *mark*) as shown in figs. 7.4 and 7.5 was 2½ inches long. In fig. 7.5 the *space* (*a-b*) was one inch long, whereas the *mark* (*b-c*) pulse was one and one-half inches long. The length of the whole cycle (one *space* and one *mark*) was two and one-half inches. Thus, 2.5/2 = 1¼ inches, which represents 100% as the length of the *mark* and *space* if distortion did not exist as shown in fig. 7.4. The *mark* space was elongated ¼ inch or 0.25/1.25 or 20% which indicates 20% mark distortion. The important question is: Is it *bias distortion* indicated by the example of fig. 7.5 or is it really *end distortion?* The trace on the scope could have been adjusted, just as easily, so that the *mark* pulse came first, as in fig. 7.6. One must conclude that it takes more sophisticated equipment than this to distinguish between the two. This certainly shouldn't bother the RTTY'er as he shouldn't have a fondness for either. It might satisfy one's curiosity to know if it's bias distortion or end distortion, but it's far more important to get rid of it, whatever it is!

Other Test Set Uses

In monitoring the trace of a polar relay keying action, one not only is able to observe distortion as outlined above, but other relay faults as well. Contact bounce, dirty contacts, or improperly aligned contacts can also be detected. These show up as a ragged, or discontinuous trace, whiskers on the trace, *etc.* instead of a smooth, straight line, as shown in figs. 7.4, 7.5 and 7.6. In addition, the test set can also be used in connection with a distortion measuring set (plugged into J_9 or J_{10}) to *read* the percentage of distortion present.

I-193-C Polar Relay Test Set

The increasing availability of the I-193-C Polar Relay Test Set on the surplus market from a number of sources, warrants a general discussion of this important piece of test gear for the RTTY'er. The unbelievable prices at which these units are being advertised on the surplus market makes it one of the best surplus buys around. A further incentive for covering this test set is that it is for the testing of the popular polar relays previously discussed. (215-A, 255-A, and D-164816).

Polar relays are so much a part of RTTY that the addition of an I-193-C polar relay test set to one's shack should certainly enhance one's pleasure of RTTY. This test set is a good companion instrument to the polar relay keyer test set just covered. One is used in checking and measuring relay distortion and the other is used as an aid to getting rid of the distortion.

Basically, the test set has three purposes. Probably the most important of these is in the testing and adjusting of polar relays for bias distortion. The second, and possibly the next in importance is in the use of the set for making proper sensitivity adjustments. Lastly, the test set contains a dot-generator circuit. This signal is of inestimable value around any RTTY'ers shack. All of these features will be covered in detail.

Physical Description

The test set was made in three models I-193-A, I-193-B and I-193-C. We are principally concerned with the 1-193-C model. The test set is considered portable as it is mounted in a trunk type carrying case with handles although it weighs 63 pounds. The test set panel is standard 19 inches wide and drilled for rack mounting. No adapters are required if one desires to remove the set from its portable carrying case and mount it in a standard 19-inch rack or rack cabinet.

Figure 5.18 gave a general view of this test set. All of the controls, sockets, power connections, *etc.*, are located on the front panel. The test set uses two polar relays which plug into two of the three sockets located in the compartment under the hinged metal lid located at the left edge of the front panel. The extra socket here is for storing a spare relay. Two spare relays are also supplied with the test set and they are stored by being plugged

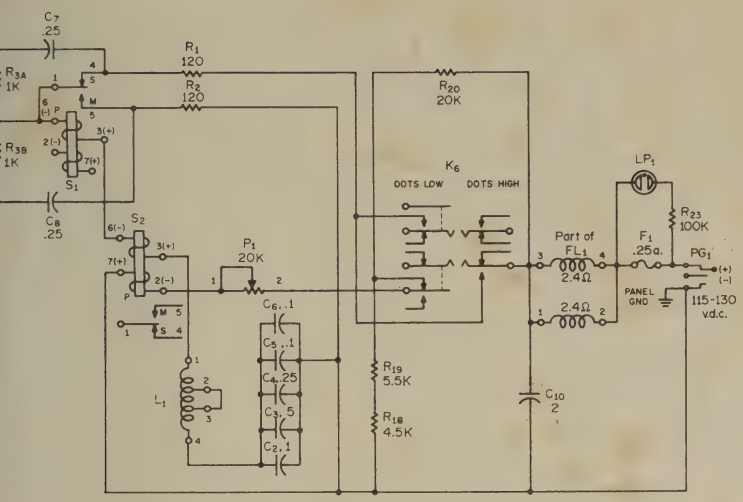


Fig. 7.7—Schematic of the 20 c.p.s. 1-193-C Test Set oscillator circuit.

nto two of the three sockets for spare relays. This is located in the compartment under the hinged metal lid located at the right edge of the front panel. These compartments allow space for storing the various cords supplied with the set. A permanent type instruction sheet occupies about two-thirds of the inside surface of the lid. The other inside lid space is taken up with a spare fuse and lamp case, and a rather extensive set of polar relay tools. The thickness gauge contains 12 leaves for thicknesses ranging from 0.002 inch to 0.018 inch. These gauges are used for adjustment of the relay contact gap for armature travel, as previously outlined. The burnisher tool is supplied with six burnisher blades and six wire burnishers that all fit into the fountain pen type barrel handle. This tool is used in cleaning and burnishing relay contacts. The adjusting keys are to be used to adjust relay contact gap and pole-piece screws. The file is a jewelers type, #6 cut, and should be *used sparingly* to dress relay contacts. The four polar relays and relay maintenance tools alone are worth a considerable portion of the purchase price being asked for these test sets on the surplus market.

Electrical Description

The chief use for the I-193-C Polar Relay Test Set is, as the name implies, to test and aid in the adjustment of polar relays. The primary tests are for bias and for sensitivity of operate-non-operate current values. In addition, the test set may be used as a source of dot signals which are actually equally spaced on-off electrical impulses. This feature was incorporated into the test sets for lining up other teletype or teletypwriter equipment, besides the polar relay. Such a signal may be used to drive the Polar Relay Keyer Test Set, instead of the square wave generator.

The set requires 115 to 130 volts d.c. at 10 watts, which can be supplied from batteries or a power supply. The simplest thing to do is use one's local loop power source, since the set requires a maximum of about 25 ma. The test set contains six basic electrical circuits. It will be recalled that, at 60 w.p.m. and a baud rate of 45.45, a signal of approximately 23 c.p.s. is created. One of the circuits, (fig. 7.7) is an oscillator that produces a 20 c.p.s. signal. The circuit used two W.E. type 255-A polar relays, S_1 and S_2, to accomplish this. These are the two relays located in the left hand compartment. Naturally, these two relays must be in proper adjustment in order for oscillator circuit to function properly. There is an oscillator circuit that produces a 10 c.p.s. signal which is similar to that of fig. 7.7.

The schematic diagram of the test set circuit for determining the bias of a relay under test is shown in fig. 7.8.

The Oscillator Circuit

The 20 cycle oscillator circuit is shown in fig. 7.7. The frequency of the circuit is determined from the series resonant circuit composed of inductor L_1 and the bank of capacitors C_2, C_3, C_4, C_5 and C_6. This resonant circuit is shock excited from the action of polar relays S_1 and S_2.

Polar relays S_1 and S_2, in fig. 7.7, must be operating properly before the test set can be used to test other polar relays, or as a source of alternating current signals. This can prove to be a sticky problem unless one has two properly adjusted Western Electric Type 255-A relays to start with. The test set is equipped with a 100-0-100 milliammeter, as shown in fig. 5.18. This meter should vibrate

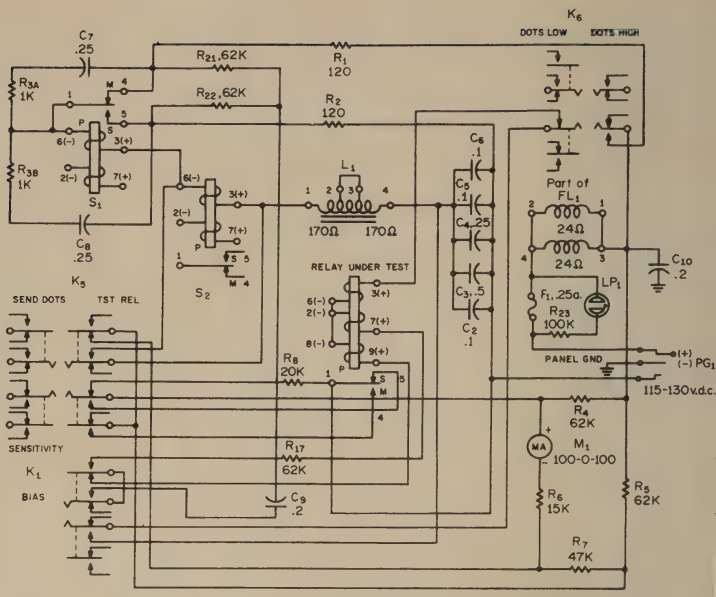


Fig. 7.8—Schematic diagram of the 1-193-C Test Set circuit for testing bias of a relay under test.

near its zero position, making equal excursions to either side of this point when switch K_6 is put in the respective "dots high" and "dots low" positions. This is an indication that polar relays S_1 and S_2 are in proper adjustment. If none of one's relays can pass this test, then one must be able to borrow two properly adjusted relays or face the task of first properly adjusting two relays without the use of the test set. One might be inclined to ask at this point, "If this can be done, then what is the point of obtaining an I-193-C Test Set in the first place?" Actually, the test set would be of some value under such circumstances, since one could plug in the relay, which is being adjusted, in socket S_1 or S_2 from time to time as it is being adjusted in order to check its operation. One should probably find or properly adjust a relay for socket S_1 first. The set may be used as a source of a.c. to test other RTTY gear after relays S_1 and S_2 are functioning properly.

I-193-C Test Set Summary

There are numerous individual circuits in the I-193-C Test Set manual, such as the circuits shown in figs. 7.7 and 7.8. Space does not permit the reproduction of all of those circuits here, nor does space permit a further discussion of their functions. As previously mentioned, one of the important functions of the test set is in the determination and adjustment of polar relay sensitivity. This and the other functions are adequately covered with numerous circuits and pictures in the 98 page manual.

DMS-1A Distortion Set

It was indicated earlier that the accuracy o the author's polar relay keyer set could b checked by simply plugging a distortion meas uring set into jacks J_3 and J_9 provided fo that purpose. The set used was an Atlanti Research Corporation Distortion Measurin Set, Model DMS1A.

A close-up view of the front panel of th DMS-1A distortion measuring set is shown i fig. 7.9 (Atlantic Research Corp.[17]) The cir cuit diagram is shown in fig. 7.10 but n circuit values are given since this instrumen is patented. This should not cause too muc concern since the material given here is no

[17] Shirley Highway at Edsall Rd., Alexandria Va.

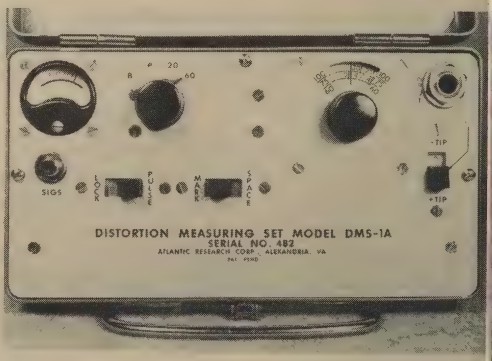


Fig. 7.9—Close-up view of the DMS-1A Distortion Measuring Set showing control locations and designations.

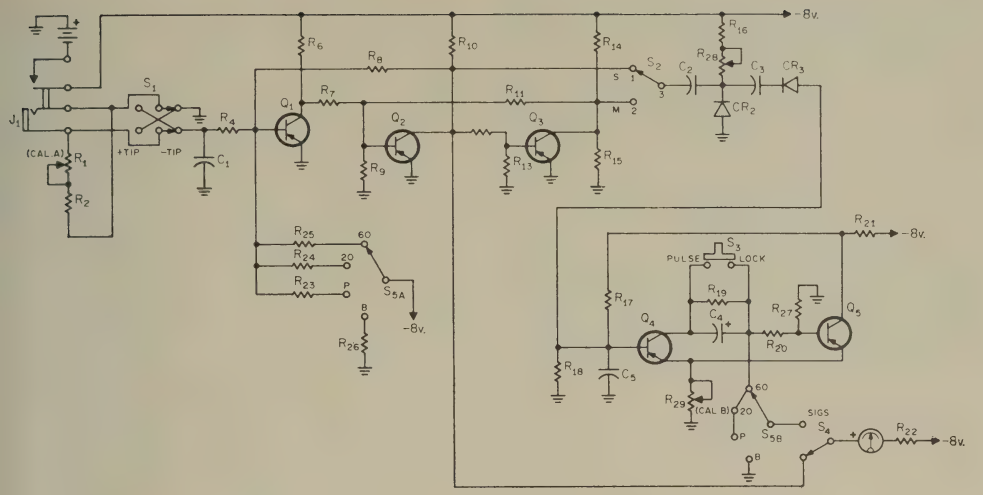


Fig. 7.10—Circuit of the Atlantic Research Corp. Distortion Measuring Set, DMS-1A.

or building or duplicating the distortion set ut for the purpose of shedding some light pon the operation and use of the device.

This set is completely transistorized and bat- ry operated. It is relatively simple to operate nd the instructions are printed on a card that mounted in the detachable lid of the instru- ent. A single 8 volt mercury cell powers e set and provides for more than 250 hours f operation. It is possible to check the bat- ry voltage by means of the front panel eter. An inspection of the close-up view of e set discloses that there is no ON-OFF switch n the front panel. The set is turned on and ff by means of a set of contacts on the put jack.

The jack plugged into the input may not ways provide a properly polarized signal so ere is a reversing switch located on the right and side of the front panel. It is the sliding vitch designated —TIP and +TIP. This vitch reverses the polarity without opening e teletype circuit that is under test.

The set is extremely compact: it measures ½ × 6½ × 2½ inches (including the pro- ctive lid over the front panel) and weighs ½ pounds, including the battery. The set is ite flexible, since it will operate at the ree most popular teletype baud speeds of .45 (60 w.p.m.), 56.9 (75 w.p.m.) and 74.2 00 w.p.m.). An important feature, but of ss interest to amateur RTTY'ers, is that ac- rding to the manufacturer, it will accept all de formats, including 6.0, 7.0, 7.28, 7.42, 5, 8.42, and 10.42 unit-element characters tart-stop or synchronous). Distortion can be easured in circuits whose neutral loop cur- nts are 20.0 or 62.5 ma as well as polar rcuits. The accuracy of the set is ±2 percent distortion, when the set is properly calibrated, and it has an input impedance of 150 ohms non-reactive (series connected to telegraph cir- cuit).

Theory Of Operation

The DMS-1A Distortion Measuring Set uses the "short-pulse theory" of measuring teletype- circuit distortion. This simply means that you measure individual pulses that have been shortened. A shortened *space* pulse gives a longer *mark* pulse, which means marking dis- tortion. Likewise, a shortened *mark* pulse gives a longer *space* pulse, which means spacing distortion.

Figure 7.11 shows a simple resistance-ca- pacitance (*RC*) timing circuit with a peak reading voltmeter connected across capacitor *C*. Let us suppose that capacitor *C* is charged to 10 volts and that the charging voltage is then removed. If switch *S* is closed, the capaci- tor starts discharging. The time that it takes for the charge on the capacitor to be dissipated and the voltage *E* to be reduced to zero is dependent upon the capacitance of *C* and the resistance of *R*. The capacitor *C* is analo- gous to a reservoir. Its storing ability is in- creased as its value of capacitance is increased. A higher value of *R* means that the discharge current is smaller than it would be if *R* had less resistance.

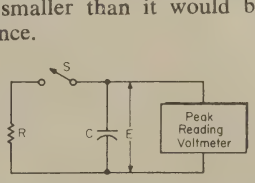


Fig. 7.11—Basic R-C timing circuit discussed in the text.

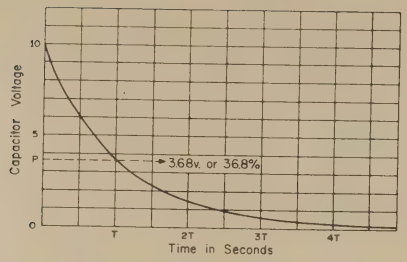


Fig. 7.12—Curve showing the non-linear nature of the discharge of a capacitor through a resistor in a circuit as shown in fig. 7.11.

It is noted that $T=RC$, where T is the time in seconds for the voltage in the above instance to lose 63.2 percent of its voltage (6.32 volts), R is the circuit resistance in ohms, and C is the capacitance in farads. C may be in microfarads if R is in megohms. The values of C and R could be selected so that the time is one second, for instance. The time constant T can remain at one second even if the capacitance of C is decreased *if* the value of R is *increased* accordingly so that the product of RC is still equal to one second. The discharge of the capacitor is not linear as shown in fig. 7.12. In fact, the last small portion of the charge is longer in dissipating, tending to extend the time considerably, as also shown in fig. 7.12. A further inspection of the voltage-decay curve of fig. 7.12 shows that the major portion of the capacitor charge, as represented by the voltage across it, is dissipated much earlier than the time at which the capacitor becomes completely discharged (voltage across it reaches zero value). It will be noted that at unity time constant (T in fig. 7.12) that the remaining capacitor charge voltage is 3.68 volts (point P) or 36.8% of its original voltage of 10 volts. Considered in the light of discharge, the capacitor has lost 63.2% of its charge or 6.32 volts. Thus, $2T$, $3T$, *etc.*, represent times of twice the time of time constant T, three times the time of time constant T, *etc.* For instance, if T was 6 milliseconds, then $2T$ would simply be 12 milliseconds.

The time constant, T, has many applications in radio and electronics. We are interested here in its application to the measurement of distortion in the DMS-1A Distortion Measuring Set.

The time constant T can certainly be more than one second by a proper selection of the value of R and C. For many applications the time constant T is a fraction of a second which is the case in this instance.

The value of C and R in fig. 7.11 can be so chosen that, for all practical purposes, the voltage E, across C, is zero at the end of 22 milliseconds. Twenty-two ms is the standard length of a *mark* or *space* pulse in the unit 60 w.p.m. teletype code used by th radio amateurs. If the discharge time of C i 22 ms, then at any lesser time, such as 16½ ms there would be a voltage remaining acros C. In this instance, this voltage would repre sent 25 percent distortion (See fig. 5.27). Tha value of voltage reading on the peak readin voltmeter would indicate the 25 percent distor tion calibration point. The scale of a peal reading voltmeter can be calibrated directly i percent distortion using this procedure.

If switch S (fig. 7.11) is closed at the in stant of the *space-to-mark* transition an opened on the following *mark-to-space* transi tion, this gives us a distortion (if present) measurement of a *mark* pulse. Likewise, t measure spacing distortion, switch S shoul be closed at the instant of a *mark-to-spac* transition and opened on a *space-to-mark* tran sition.

It will be recalled that the voltmeter across C was a peak reading device. The DMS-1A distortion measuring set is also a peak reading device, holding the highest reading while ignoring longer pulses (lower voltage, lower distortion, stop pulses, as well as two or more like pulses which occur together). All of the switching, sampling, *etc.*, associated with the distortion measurements in the DMS-1A, is done electronically. A faster speed, such as 75 w.p.m. means shorter pulses. The 5 "intelligence transmitting" pulses of a 75 w.p.m. signal are 18 milliseconds long. The *time base* of our measurement must be narrowed down. This is done by reducing the resistance, R, in fig. 7.11. This is done in the DMS-1A and the same scale and distortion calibration is used. This is true for the various other code speeds covered by this distortion measuring set.

A monitor to give an alarm on distortion can be devised using the aforementioned RC network. A circuit may be set up so that any pulse coming along, which is shorter than the standard pulse (with its subsequent standard time base), will trip a flip-flop circuit which in turn sets off an alarm. The shorter the pulse, the higher the charge left in capacitor C, fig. 7.11. The flip-flop circuit may be preset to operate at any predetermined voltage. This predetermined voltage represents some distortion calibration point. A monitor alarm then can be devised so that it sounds an alarm at the preset level of distortion.

Operation Of The DMS-1A

A close inspection of the front panel of the close-up view of the DMS-1A makes its operation almost self-explanatory. There are very few controls, and the function of each of these is, for the most part, obvious.

The test set is connected in series with the ocal loop or teletype circuit to be checked or distortion. Two good examples of this can e found in the Polar Relay Keyer Test et previously covered. Any distortion present n the plate circuit of the 6AQ5 keyer tubes nay be measured by placing the DMS-1A set n series with the plate circuit of the two eyer tubes. This is accomplished by plug-ing one end of a patch cord into the input ack of the DMS-1A distortion measuring set nd the other end of the patch cord into jack J_3, J_4 or J_5 (fig. 7.3). Any distortion present n the keyed output circuit of the polar relay ircuit may likewise be measured by placing he DMS-1A set in series with this circuit by he use of jack J_9 or J_{10}—

It is a simple matter to use the DMS-1A listortion measuring set. It is placed in series vith your local loop or other circuit where eletype distortion is suspected to exist. This s done by a plug to the set's input jack, J_1, is shown in the circuit of fig. 7.10. It may, or may not be necessary to reverse the polar-ty switch, designated as S_1 in the circuit, and as +TIP and —TIP on the front panel. Press SIGS button, S_4, located on left side of front panel under the meter. If signals are present n the circuit, the meter will pulse when the polarity switch is correctly positioned. If the meter does not pulse up and down (usually somewhere around half scale) then this is a good indication that the polarity switch is in the wrong position or else there is little or no signal present.

The internal battery voltage can be checked by rotating the selector switch, designated, as S_{5A} and S_{5B} in the circuit diagram (located just to the right of the meter) to position B. The battery should be replaced if the meter pointer comes to rest to the left of the indicator line on the meter scale.

Next, the selector switch should be rotated to the proper position for the circuit under measurement (P for polar, 20 ma or 60 ma). The PULSE-LOCK switch should be placed in the PULSE position. Place the MARK-SPACE switch in either position. Set the distortion calibrated dial (turning clockwise) at some value higher than the value of distortion expected. Slowly rotate the dial counterclockwise while observing the meter pointer (not the dial). Stop the counterclockwise movement of the dial when the meter pointer definitely shows an upward pulsing movement. Turn the dial back (clockwise) just to the point where the pulsing action of the pointer stops and read the distortion percentage.

The dial is calibrated for three teletype speeds, 60 w.p.m., 75 w.p.m. and 100 w.p.m. The "60" scale would be used, since amateur RTTY is at 60 w.p.m. If the above procedure

Fig. 7.13—The model DMS-1A-5, an improved distortion measuring set with direct meter calibration.

was done with the MARK-SPACE switch set on MARK then the procedure should be repeated with this switch set on SPACE. The important thing is that this procedure be carried out for both *mark* and *space*.

The set will not indicate seldom encountered distortion which causes only lengthening of unit *mark* and *space* pulses. The set can be used as an unattended monitor to indicate any distortion greater than a predetermined level. This is accomplished by switching the PULSE-LOCK switch to the LOCK position and setting the distortion calibrated dial to the desired preset distortion value on the 60 w.p.m. scale. When a pulse comes along that is greater than this value, the meter swings upward and locks into position. The pointer is released to return to its normal position by pressing the SIGS button.

It will be recalled that the distortion set calibrations for 60 w.p.m. are for a baud speed of 45.45 and an element time length of 22 milliseconds. This, in turn, means that the square wave generator signal to the input of the Polar Relay Keyer Test Set *must* be set to 23 cycles.

If the square wave generator frequency is increased, the pulses will be shorter than 22 ms and the distortion meter will give a false distortion reading. This is easily demonstrated by increasing the frequency and checking with the distortion meter. The false reading increases with the frequency. This is easily detected since it gives a reading of distortion for both *mark* and *space* since both pulses are shorter than 22 ms.

If the square wave generator is set to a frequency lower than 23 cycles the square wave pulses from the generator now become longer than 22 ms for which the set is calibrated. Distortion could be present in the relay keyed output due to bias distortion in the

relay and the distortion set would not show it unless the shortened pulse was less than 22 ms. Even then the reading would be less than the actual distortion present.

Consider a frequency of 15 cycles which would give 30 square wave pulses (half cycles). 1/30 = .033 or 33 milliseconds which would be the length of one pulse. Bias distortion of 25 percent present in the circuit would lengthen one pulse to 41 ms and shorten the other to 25 ms. Since 25 ms is more than 22 ms for which the distortion set was calibrated, the set would not indicate that any distortion was present. It can be seen from this, that it is important that the square wave generator be set at 23 cycles and that we have some means of knowing that the generator calibration is right if we doubt its accuracy.

The use of the DMS-1A set in connection with the author's Polar Relay Keyer Test Set was covered first since it has been thoroughly described and discussed. The DMS-1A set may just as readily be used to measure RTTY distortion in any RTTY circuit adju ed for either a current of 20.0 or 62.5 m This includes local loop circuits containir either the teletypewriter keyboard transmitt contacts or selector magnet coils or both, suc as circuits shown in figs. 3.1 and 3.5

Other Distortion Sets

The Atlantic Research Corporation mak a complete line of teletype distortion measu ing sets as well as numerous associated instr ments and devices. Most of their distortic measuring sets are for commercial applic tions and are quite sophisticated, as well expensive. The DMS-1A series is made quite a number of different models, such DMS-1A-1, DMS-1A,2, etc. Of particular in terest to the amateur RTTY'er is the DM 1A-5, shown in fig. 7.13. In the set the di tortion can be read directly from the mete which has a scale calibrated in distortio percentages.

8

MACHINE ADJUSTMENTS

ACQUIRING and operating a teletype machine or the first time parellels one's experience in buying a new car. At first, its operation is unamiliar to us. Gradually, with use, and with the id of literature on the subject, one gains more nderstanding of the machine. The following naterial is designed to give the reader that aid.

Teletype Machine Servicing

It is human nature to try to get the most with he minimum amount of effort put forth on omething. The teletype machine is no exception. Many RTTY'ers simply operate their machine with little or no attention until it quits or errors come thick and fast.

A teletypewriter must be given reasonable are and servicing if one is to expect continued rouble-free operation from the machine during ts useful life. A good question at this point night be: "What is the length of that useful fe?" Naturally, the life of machines varies conderably, depending upon the previous usage commercial or military) and the treatment it ets in the hands of an amateur. Most of the nachines that come through proper channels rom Bell companies have many years of life eft. More machines become inoperative from eglect than from use and this observation lone should indicate to the reader the importance of giving his teletype machine at least easonable care.

There are established service organizations vailable that one can turn to for the servicing f a car or household appliance, but there are very few such places where one can have teletype equipment serviced. Often this involves crating, packing and shipping to some other city. There are no convenient service stations where the machine may be taken for routine inspections, cleaning, greasing, *etc.* You must learn to do basic maintenance yourself. This means acquiring a certain amount of "savvy" in regard to teletype equipment. Fortunately, the use of the machine in amateur RTTY is almost nil (with some exceptions) compared to commercial use and it will usually give good service in amateur use, with a bare minimum of attention.

Basically, there are three requirements of servicing that must be satisfied if one is to expect free operation of a teletype machine. The machine must be periodically *cleaned, lubricated, and adjusted.* One is just about as important as the other.

Figure 8.1 lists a typical set of tools and materials used to service a machine such as the Teletype Model 15. This list gives the identifying numbers, names, description, and in some instances, the purpose of the tool or item. At first glance, one may be discouraged by the sheer number of items. A closer look reveals that many of the items are already on hand, or reasonable substitutes are readily available.

When To Service

A teletype machine that has been in storage or otherwise inoperative for some time may need a certain amount of servicing before it is

Gauge: tape.
Gauge: set; wire: 0.006" to 0.025".
Gauge: set; wire: 0.065" to 0.080".
Gauge: set; flat: 0.002" to 0.010".
Pin: gauge.
Gauge: perforation of feed wheel.
Gauge: armature locating.
Scale: 32 oz.
Scale: 12 lb.
Hook: spring; pull.
Hook: spring; push.
Paper: cleaning; Bell Seal bond.
Cloth: emery; crocus.
Paper: sand; flint: #000.
Cloth: emery; #0.
Mirror: dental; WECo No. 376A; 6¾"x1¼" overall.
Bender: spring.
Tool: locking bail: finger holding.
Tool: finger bending.
Gun: grease; Teletype No. 88975.
Magnet M-129; bar; steel; 6 x ¾ x ¼".
Test Unit 1-236; 5½ x 3¾ x 3¼"; includes neon lamp and target lamp.

Fig. 8.1—Listed above are some of the typical tools and materials used to service a teletype machine such as the Model 15.

Fig. 8.2—Bottom view of the Teletype Model 15 keyboard showing the lubrication points. Each point requires 1 or 2 drops of Lubriplate No. 2 or SAE 10.
1. Selector bars in slots and rollers.
2. Universal bar pilot screw on bearings.
3. Trip off pawl link joint.
4. Keylevers on Keylever shaft and in rear comb.
5. Locking levers between pins in selector bars.

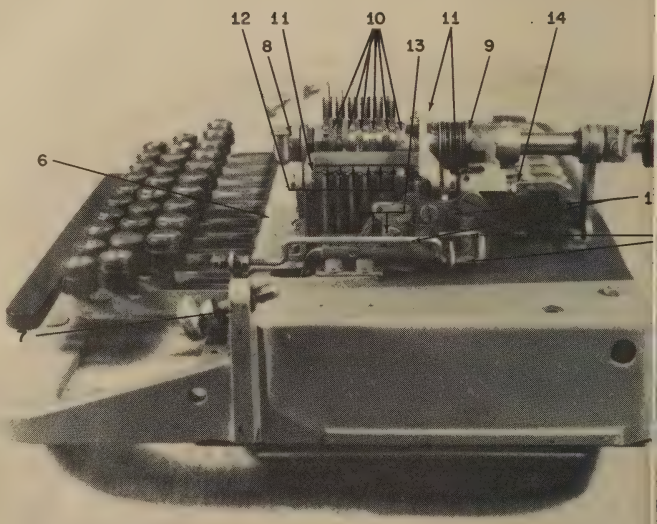


Fig. 8.3—Top view of the Model 15 keyboard showing the lubrication points. Points marked A receive 1 or 2 drops of SAE 10 and those marked B receive Lubriplate No. 630-AA.
6. Keylevers in front Comb. A
7. Space bar loop on space bar loop shaft. A
8. Keyboard shaft (2 oil cups). A[1]
9. Keyboard clutch - sliding member. A
10. Cams, on surfaces. B[2]
11. Locking loop pilot screw bearings and rollers. A
12. Contact lever pivoting shaft and guiding comb. A
13. Locking levers in locking lever comb. A
14. Clutch throw-out lever bearings. A
15. Trip-off and intermediate lever pawls. A
16. Keyboard transmitter gear. A[3]
17. Repeat space rod on each bearing and points of contact. A

[1] *Fill cups.*
[2] *Light film.*
[3] *Sparingly.*

ut back in service. For instance, all oil cups nould be checked and filled if necessary. The ondition of the clutch on the main drive from ne motor should be checked. The clutch nould be kept *saturated with fresh oil* at all mes; otherwise, the machine may start print-ng gibberish.

Preventive Maintenance

The teletype machine is an excellent example f where *preventive maintenance* will pay good ividends. Preventive maintenance is designed o *avoid* failures and breakdowns by giving the nachine routine servicing at regular intervals. Preventive maintenance should not be done imply for the sake of doing it, or on a hit and niss basis. The manufacturer suggests that there re six basic maintenance operations: Feel, in-pect, tighten, clean, adjust and lubricate. These asic maintenance operations are covered in the ollowing sections.

Feel

Feel has to do mainly with the location of above normal temperature of parts. Overheat-ng of parts can be due to lack of oil or grease, inding due to an accumulation of gummy sub-tances on moving parts or bearings, or to parts ightened beyond allowable limits. Warped or ent parts can also cause overheating. Oper-ation of the machine in a confined or otherwise unsatisfactory location can also raise the oper-ating temperature. The feel test can also locate loose parts and certain mechanical irregularities. One may be able to locate binding parts or loose parts by feeling and gently prodding around the machine.

Inspection

A careful inspection of a machine should be nade before attempting to give the machine reventive maintenance. A careless observer, or ne unfamiliar with his machine, may overlook vidences of minor troubles. Unfortunately, nany such minor troubles can eventually lead o more serious troubles or breakdowns. Often lefects are sufficiently minor so that they do ot mar the performance of the equipment for he time being. This makes them more difficult o detect by an inexperienced person. One hould make every effort to learn enough bout their machine so that they can recognize he normal functions of the machine as well as bnormal functions. After you have become ccustomed to the operation and sounds of the nachine, you are in a better position to detect nything out of the ordinary, especially if the ound of the operating mechanism changes suf-iciently to be noticed. All malfunctions of the nachine are *not* accompanied by a change in ound of the moving parts. It may take a hickness or spacing gauge, or a spring tension scale to determine if all is in order with regard to certain functions or operations of the machine.

The inspection of the machine can well be the most important part of preventive maintenance. This raises the question of just what we should look for. The machine should be inspected for cleanliness, whether it is fairly clean or covered with grime and dirt, particularly in the moving parts. One should determine if the machine needs lubricating or has an excess of lubricant. Lubricants, after a long while, or under certain operating conditions, can become hardened and gummy and should be completely removed and replaced with fresh lubricant.

Besides those items already listed, the machine should be inspected for corrosion, moisture accumulation, mildew or fungus growth in tropical or high-humidity locations. One should look for overheating, tension, tightness, wear, placement and adjustment, loose electrical contacts, frayed or deteriorated wiring, arcing, dirty or pitted electrical contacts, as well as broken or warped parts.

Cleaning

The cleaning of a teletypewriter need not be a bothersome chore. If done leisurely and carefully it gives one a chance to observe the many parts and their functions. A lint free, clean, dry cloth should be used to wipe off dust, grime, excessive lubricant and other foreign materials. Naturally, there will be places where even a small strip of cloth will not fit, so it may be necessary to fold a piece of lint free cloth over a slim screwdriver or other flat object to fit between the function levers, vanes and inside the printing bail, as well as other hard to reach places. Do not force a cloth covered screwdriver between two parts so that they are bent or otherwise damaged. *Do not rush.* Look before you probe and wipe. A small brush can also be used to clean the places more difficult to reach. In fact, it will help to have several small brushes with handles of varying lengths as well as bristles of varying stiffness. The faces of the type bar pallets should be wiped clean with a piece of cheesecloth that has been dampened with a dry cleaning solvent. A typewriter brush will aid in this but be careful not to bend the type bars during this operation. A stiff brush should be used to clean between the key levers and around the transmitting mechanism. Carbon tetrachloride may be used to clean electrical contacts.

Lubrication

A teletype machine should certainly be lubricated, but the lubricant should be used *sparingly*. Too much lubricant on a machine frequently speeds up the accumulation of dust and other foreign materials which works its way

into bearings and other meshing and moving surfaces. This provides a cutting compound that causes excessive and unnecessary wear.

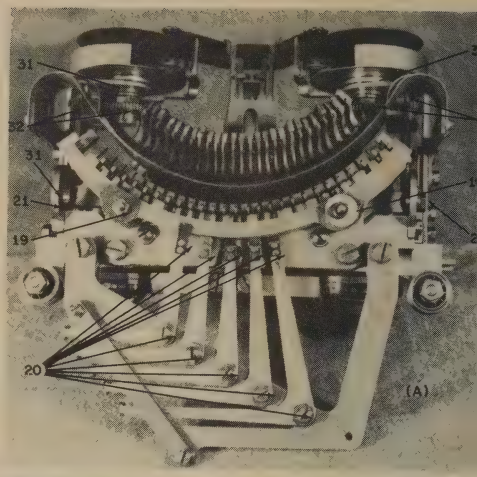
Excessive lubricants, together with dust and other foreign materials may eventually harden into a gummy substance that will impede or even prevent certain mechanisms from functioning at all. In addition, excessive amounts of lubricant makes the cleaning job more difficult.

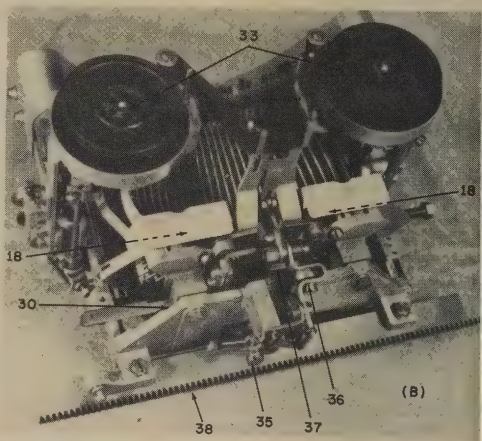
In other words, lubricate your machine, by all means, but use the lubricants sparingly and wisely.

The easiest way to keep from overlubricating a machine is to never try to squirt one or two drops of oil from a can, however small it may be. A better method of applying oil to a lubrication point where only one or two drops are required (a lot of oil for any one spot on a teletype machine) is to use a short piece of #22 wire. Simply dip one end about a half inch into the oil and apply to the lubrication point immediately. One is not always able to put the oil exactly on the right spot. In such instances the misplaced oil should be carefully wiped off.

A teletype machine requires two kinds of lubricant, a grease and an oil. Any good grade of oil equivalent to SAE 10 should be satisfactory. One may use Lubriplate No. 2 oil.[18] The selection of the grease is not quite so simple. Oily or "greasy" types of grease, such as the common "cup grease" should be avoided if possible. Make every effort to obtain a special grease made for this or similar purposes.

[18]Fiske Brothers Refining Co., Newark, N. J. and Toledo, Ohio.





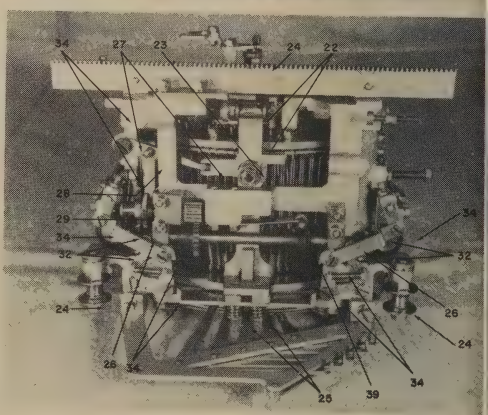


Fig. 8.4—Front (A), and back (B) and bottom (C) views of the type bar carriage showing lube points as well as general construction. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubriplate No. 630-AA.

18. Type bars at segment slot. A
19. Code bars at posts. A
20. Code bar bell cranks on wearing surfaces. A
21. Pull bar bail on guide rollers and guide surface. B[1]
22. Plunger surface and rollers. B[1]
23. Plunger roller. B[1]
24. Carriage support rollers. A
25. Ribbon reverse bail. A
26. Ribbon feed shaft bearing. A
27. Ribbon feed pawl operating lever. A
28. Ribbon feed pawl pivot screw. A
29. Ribbon feed ratchet. A
30. Ribbon lockout bar at type bar segment slot. A
31. Ribbon feed shaft, on upper and lower bearings. A
32. Ribbon feed mechanism. A[1]
33. Ribbon spool shafts on bushings (remove spools). A[2]
34. Ribbon reverse shafts, upper and lower bearings, arms, pawls, and levers. A
35. Margin bell pawl. A
36. Ribbon shift lever and roller. A
37. Oscillator lever shoulder screw and carriage casting slot. A
38. Type bar carriage rack, space shaft pinion and travel. A
39. Ribbon feed shaft detent. B

[1]*Sparingly.*
[2]*2 or 3 drops.*

After all, like oil, the smallest can of grease that you can buy will probably outlast the machine. Another Lubriplate product is useful here, too. Lubriplate No. 630-AA is an off-white colored grease. It sticks well and is not as messy as the general run of cup greases.

Lubrication Points

Up to this point only the Teletype Corporation Model 14, 15 and 19 Teletype machines have been covered since they are in more general use than any of the others. The Teletype Corporation manufactured printer TG-7-A and Teletypewriters TG-7-B and TG-37-B as covered by the War Department Technical Manual TM-11-352. This equipment is the military version of the Teletype Model 15. They are essentially the same: however, there is a variance here and there. Quite a number of these machines are in the hands of the amateur RTTY'ers.

It is beyond the scope of this text to give complete data on every lubrication point for every teletype machine made or even all of those in general use by amateurs. Naturally, these points vary with the type of machine. In addition, there are variations in the same machine when more than one model is involved. A model 15 teletypewriter is shown in figs. 8.2 to 8.4 illustrating a portion of the lubrication points of this machine.

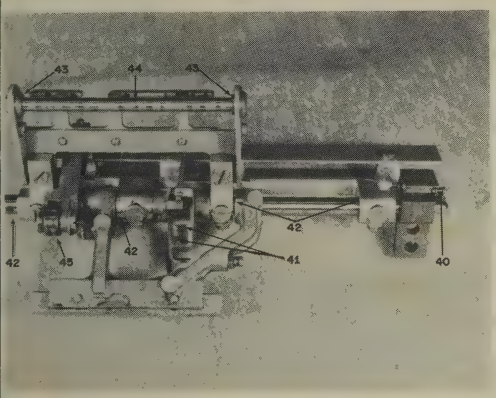


Fig. 8.5—View of the Model 15 bail unit assembly showing the general construction and lubrication points. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubriplate No. 630-AA.

40. Bail assembly shaft bearings (2 oil cups). A[1]
41. Between spacing pawls. A
42. Function bail and printing bail operating arm bearings. A
43. Function lever bail roller (two bearings). A
44. Roller surface. B
45. Functioning bail and printing bail operating arm and rollers. B[2]

[1]Fill cups.
[2]Sparingly.

Figure 8.4(c) gives the lubrication points for the bottom of the type bar carriage. Lubrication points for the bail unit assembly are shown in fig. 8.5. Figure 8.6 shows the lubrication points for the bottom of the typing unit. This figure also gives an excellent view of the drive shaft with the selector mechanism clutch shown in the right half of the picture. A portion of the selector mechanism may be seen further to the right and the bottom edge of the range finder on the extreme right. Unfortunately a number of important lubrication points are not sufficiently visible in the bottom center fore-front of the fig. 8.6 to point them out and these are described in the caption.

Lubrication points for the carriage return mechanism are shown in fig. 8.7.

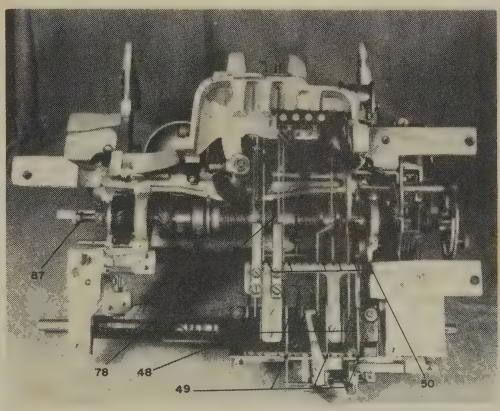


Fig. 8.6—View of the bottom of the Model 15 typing unit showing the lubrication points. Note also the general view of the main shaft. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubriplate No. 630 AA.

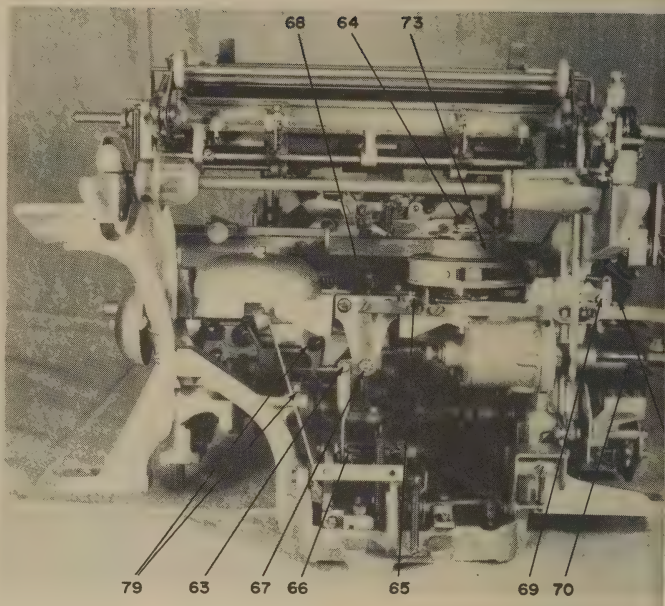
48. Function levers in vane frame slot. A
49. Function levers in slot in break mechanism plate. A
50. Push bars and latch bars in function lever comb. A
78. Bell latch bar at point of engagement with latch. A[1]
87. Main shaft. A[2]

Lubrication Point Not Visible

Carriage return clutch members prongs. A
Carriage return latch bar at point of engagement with latch. B[1]
Carriage return clutch release fork and operating lever bearings. A
Carriage return push bar and latch bar operating lever shoulder screw. A
Carriage return operating lever stop screw. B

[1]Sparingly.
[2]Hold right end of teletype up 6" and remove oil plug. Fill shaft until oil runs out of left end.

Fig. 8.7—Lubrication points for the Model 15 carriage return mechanism. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubliplate No. 630 AA. Call-out 79 should be 74.



63. Carriage return locking bar bell crank link shoulder screw. A
64. Carriage return spring drum bearing. A
65. Carriage return spring release lever shoulder screw. A
66. Clutch release fork link shoulder screw. A
67. Locking bar bell crank upper cross bar casting shoulder screw. A
68. Locking bar and locking bar bell crank shoulder screw. A
69. Locking bar latch and left hand side frame shoulder screw. A
70. Dashpot piston rod rubbed over surface of piston. A[1]
71. Dashpot lever mounting screw, and roller mounting pilot screw at point of contact with left hand margin adjusting screw. B[2] A
73. Carriage return spring through oil holes in drum.
74. The "figures" and "letters" push bar shoulder screw. A [1]One drop, [2]Sparingly.

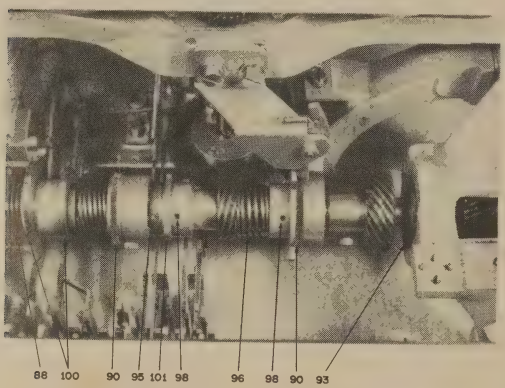


Fig. 8.8—Lubrication points for the main shaft of a Teletype Model 15 machine. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubriplate No. 630 AA.

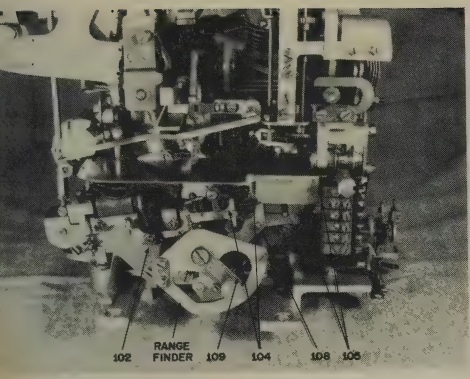
88. Main clutch sliding member. A[1]
90. Main shaft friction washers. A[2]
93. Main shaft right ball bearing. A, B[3]
95. Thrust bearing on end balls. A
96. Spacing clutch spring coils. A[4]
98. Cam unit and spacing clutch in oil holes. A
100. Main shaft cam surfaces. B[5]
101. Spacing escapement ratchet teeth. B[5]

Lubrication Points Not Visible

Main shaft (point 87 in fig. 8.6.)
Locking lever cam, felt washers on selector cam assembly. A
Selector cam sleeve on each cam peak. A
Main shaft left ball bearing. A, B[3]
Spring which compresses friction washers of cam assembly. A[6]
Main clutch caming surface. A

[1]Oil freely.
[2]Saturate.
[3]Apply 1 or 2 drops of A, turn shaft; apply thin coat of B; turn shaft a few turns; apply 1 or 2 drops of A.
[4]Permit oil to flow between prongs of driver member of spacing clutch and worm gear sleeve.
[5]Sparingly.
[6]Apply sparingly to coils (oil will flow between prongs of nut on main shaft and friction disk which engages this nut).

Figure 8.8 gives the lubrication points for the main shaft of this machine. Not shown in fig 8.7 or 8.8 is the oil plug in the right end of the main shaft. Listed as oil point 87 it may be seen on the left side fig. 8.6 (back and bottom view of unit), which also gives an excellent, but reversed view of the main shaft. Be sure to not miss this important point and the full instruc-



Ig. 8.9—Lubrication points for the Selector lechanism of a Teletype Model 15 machine. ll points are lubricated with 1 or 2 drops f SAE 10.

02. Armature bearings (2).
04. Swords and selector levers between separating plates.
105. "T" levers on all points of contact.
108. Motor stop pawls shoulder screw and lever bearings.
109. Release lever bearings, contact lever bearings and where contact lever protrudes through break mechanism plate.

tions that are given for point 87. Not shown and out of view to the left in fig. 8.8 are other main shaft lubrication points as listed in the caption. Other parts of the machine make it difficult to photograph these points without removing the shaft from the machine and after all the owner must locate and grease these points with the shaft in place.

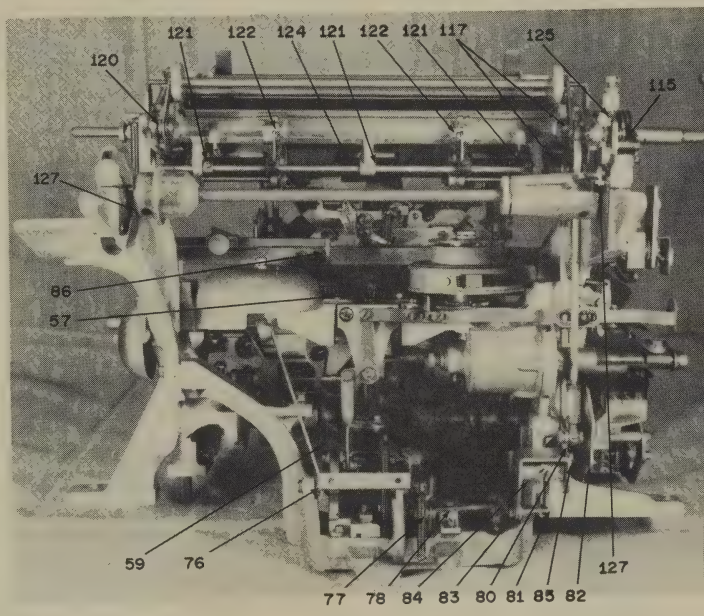
Figure 8.9 gives the lubrication points for the selector mechanism for the same machine. Not visible in fig. 8.9, and listed in the caption is the trip latch plunger, trip latch and bell crank lever, and stop lever of the range finder assembly. These points should not be overlooked in the lubrication of the machine.

Lubrication Points Not Visible

Trip latch plunger, trip latch and bell crank lever and stop lever of range finder assembly.

ig. 8.10—Lubrication points the back of the Model 15 ping unit. Points marked *A* ceive 1 or 2 drops of SAE 0 and points marked *B* re- ive Lubriplate No. 630 AA.

57. Spacing shaft in upper bearing; lever bearing fill oil cup. A
59. Spacing gear (lower) B[1]
76. Bell striker arm and arm operating lever bearings. A
77. Bell push bar and latch bar shoulder screw. A
78. Bell latch bar at point of engagement with latch. B[1]
80. Bell crank lever and operating lever shoulder screw. A
81. Bell crank lever and operating lever joint. A
82. Shift vertical link, lower and detent lever shoulder screw. A
83. Line feed push bar and bell crank lever shoulder screw. A
84. Bell crank lever mounting shaft. A
85. Vertical link and bell crank lever, lower end, shoulder screw. A
86. Margin bell shaft, 2 bearings. A
15. Shift detent roller. B[1]
17. Line feed and shift vertical links. A



120. Paper straightener rod supporting lever bearings. A
121. Pressure roller release shaft and crank bearings. A
122. Pressure roller release cam crank and shoulder screws. A
124. Pressure roller sleeves. A[2]
125. Letters and figures stop screws. A[3]
127. Paper spindle bearings. A

[1]Sparingly.
[2]One drop each.
[3]Grease ends.

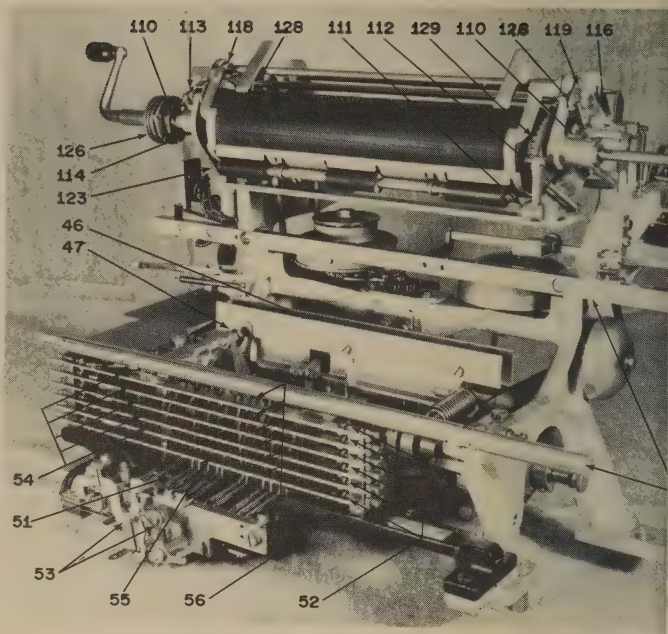


Fig. 8.11—This view of the type unit shows the various parts as well as the lubrication points. Lubrication points marked *A* receive 1 or 2 drops of SAE 10 and points marked *B* receive Lubriplate No. 630-AA.

46. Printing bail blades where plunger operating roller engages blades. A
47. Printing bail, adjusting screw head. B[1]
51. Sixth vane extension spring in slot in letters push bar. A
52. Vane Pilot screw bearings. A
53. Send-Rec. Break mech. intermediate lever mtg. screw and reset lever pivot screw. (Get no oil on friction spring washer of Send-Rec-Break mechanism T lever.) A
54. Vane's front edges where bell crank's slotted ends slide in engagement with vanes. A
55. Sixth vane detent roller. A
56. Locking function lever. B[2]
72. Type bar carriage assembly on upper and lower track surfaces. A
110. Shaft bearings in each shaft hub. A
111. Line feed detent lever mounting shoulder screw. A
112. Line feed detent roller. A
113. Single-double line-feed lever between flat spring and denting cam and where single-double line feed lever fits into groove in platen shaft hub. A
114. Line feed pawl and line feed lever shoulder screw. A
116. Platen unit pivot bearings. A
118. Paper knife supporting arms and paper guide bearings. A
119. Paper straightener lever bearings. A
123. Pressure roller shafts on bearing surface. A
126. Platen friction disc assembly, felt washers. A[3]
128. Line feed check lever shaft bearings. A
129. Line feed detent rachet. B[1]

[1]Sparingly.
[2]Apply grease in notches.
[3]Saturate.

Lubrication points for the back of the typing unit are shown in fig. 8.10 and fig. 8.11 for the front of the type unit. An excellent view of the various parts of the type unit is also shown. The various views given above, as well as in figs. 2.10 to 2.20 in the first part of this text, should give the reader an opportunity to study the various mechanisms as well as locate the lubrication points. These views should aid the reader in locating and identifying the various parts of his teletypewriter. Data given here covers a considerable portion of the equipment in general use by the amateur and should be a sufficient guide in the lubrication of other machines.

Adjustments

One might reason that this section heading could have just as well been "Tighten." Adjustment does not always mean "tighten as far as it will go" in all cases in a teletypewriter. Above all, one should not tighten every screw, nut or bolt, just because it can be turned. The fact that it can be turned may be because it is a part of some adjustment. In fact, loose screws, bolts and nuts should never be tightened until you have fully determined that they *are not* a part of some adjustment of spacing, tension, *etc.* Fittings should not be tightened beyond the pressure for which they are designed. Such abuses subject the affected parts to damage and breakage.

Adjustments are only to be made when they are necessary to restore normal operating conditions. It is important that *proper tools and gauges* be used to make adjustments. All adjust-

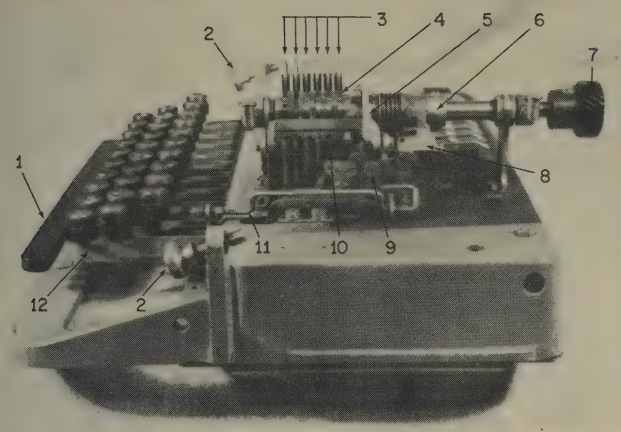


Fig. 8.12—Pictorial view of the teletypewriter keyboard including identification of major parts.

1—Space bar.
2—Thumb screws.
3—Contact levers.
4—Start-stop cam.
5—Lock loop.
6—Clutch.
7—Gear.
8—Clutch throw out lever.
9—Intermediate pawl.
10—Locking levers.
11—Repeat space rod.
12—Key levers.

nents must meet the requirements for *tolerance imits,* for clearance, speed, spring tension, *etc.* Many adjustments must be made in accordance vith a specific sequence. In some instances one djustment is so related to others that they too nust be subsequently adjusted, or at least hecked. Such an inter-relation or overlapping f functional adjustments may require several touch-ups." A beginner or inexperienced per- on should be very cautious in the adjustments hat they attempt to make. It is just as impor- ant to know *what not to do* as well as what to lo in such instances.

Sending End Distortion Source

A coverage of polar relays has been given, s well as their associated problems of distor- ion. There is still another source of distortion t the sending end and that is the teletype nachine keyboard transmitter contacts, or ending mechanism.

Earlier in the text, in the coverage of fre- quency shift keying methods, it was indicated hat such systems could be keyed directly from he keyboard transmitter contacts. Many RTTY'ers do exactly that, in fact, far too many f them do this.

The sending mechanism has five sets of char- acter forming contacts, as well as a set of start- stop contacts, six sets in all. Remember that the polar relay only has *one* set of contacts. It is certainly reasonable to deduce then, that one could expect considerably more trouble from he keyboard sending mechanism contacts, col- lectively, than from the single set of contacts f a polar relay. This then should point up to the fact that it would be much more desirable o let the keyboard transmitter contacts key a polar relay and let the polar relay, in turn, key the frequency shift keying circuit of the RTTY transmitter. There are, however, other reasons for this besides the sheer number of contacts involved.

The RTTY'er must have a good working knowledge of both polar relays and the key- board mechanism in order to cope with the distortion problems associated with each. As pointed out before, certain types of sending end distortion can be compensated for at the receiving end. In fact, there are three possible ways to do this .Some terminal units are pro- vided with special adjustable circuitry to cope with this problem. A regenerative repeater such as the surplus TT-631A may be used for this purpose. Some operators resort to moving the selector magnet range finder of their ma- chine in a last ditch effort to copy heavily bi- ased RTTY signals. There surely isn't any future to this last method. Sending end bias should, by all means, be *corrected at the send- ing end.*

Keyboard Distortion

The f.s.k. circuits discussed earlier covered both the "dry contact" (little or practically no voltage across the keying contacts) and the "wet contact" (substantial voltage across the keying contacts) method of keying. The pitfalls of dry contact keying were pointed out and these apply to polar relay contacts as well as keyboard transmitter contacts. Only solid-state switching f.s.k. circuits were given, since they are relatively simple and in universal use. With solid-state switching circuits the voltages in- volved in wet keying are not too high.

Direct keying of the radio transmitter oscilla- tor circuit by means of the keyboard contact mechanism invariably brings on *fortuitous dis- tortion* caused by keying transients. Fortuitous distortion is an erratic shortening of *mark* and *space* as mentioned earlier. This is in contrast to a systematic shortening or lengthening of *mark* and *space.* Bias and characteristic distor- tion, covered earlier, are examples of systematic distortion. Bias distortion is most prominent in

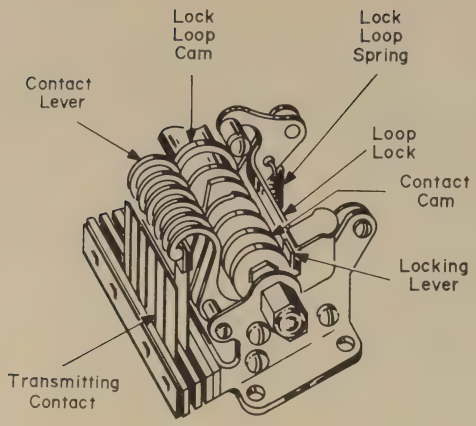


Fig. 8.13—Line drawing of only the transmitter mechanism identifying the major parts.

amateur RTTY work, with fortuitous distortion next. It was shown earlier that bias distortion is relatively easy to measure and correct, in most instances. This is not the case for fortuitous distortion. It is not a systematic or re-occurring phenomenon. Fortuitous distortion not only displaces the TTY signal in a random manner, but by various amounts as well. This makes its detection difficult and its measurement even more difficult. Most RTTY distortion measuring instruments measure the *total* distortion that is present in a circuit. *Total distortion,* as represented by the displacement of a received transition from its proper or correct time of occurrence is equal to the *algebraic sum* of the systematic (all) distortion and fortuitous distortion. It takes quite a sophisticated instrument to measure fortuitous distortion alone. Such an instrument is found in scattered commercial use. Its price and complexity does not make it practical for amateur use.

Fortunately, fortuitous distortion can be isolated and detected in a round about way. When it is present in an amateur RTTY system, it is usually traced to the TTY keyboard transmitter contacts. One should, by all means, look here first whenever it is suspected.

Much of the trouble arising from fortuitous distortion can be avoided by *not* keying the transmitter oscillator circuit directly with the keyboard transmitter contacts in the first place. Secondly, one can virtually eliminate this bothersome error-maker by proper servicing of the keyboard mechanism in accordance with the following sections on servicing of the various parts of this all-important mechanism.

Transmitter Mechanism

A general description and explanation of how a keyboard transmitter mechanism works was given earlier. A general view of the mechanism can be seen in figs. 2.11 and 2.18. Partial details of the mechanism can be seen in figs. 2.16 and 2.17. Figures 8.12 and 8.13 show additional details of this all important mechanism. A chart showing sequence for keyboard functions is given in fig. 8.14. These pictures and line drawings, together with the earlier description and explanation of how this unit functions should aid in understanding and actually performing the keyboard adjustments that follow.

Keyboard Adjustment

Proper adjustments of the associated mechanisms of a keyboard include *tension* adjustments as well as *spacing* adjustments. This requires an 8 ounce spring scale and a 32 ounce spring scale, as well as a feeler gauge. Possibly an emery board and burnishing tool may also be needed if the transmitter contacts are found to be pitted or corroded.

The keyboard should be separated from the rest of the teletypewriter, as shown in fig. 8.12, before attempting to inspect, service or adjust any parts of its mechanism. Any required cleaning operations should be carried out before making any adjustments, as this operation could alter spacings of parts as well as spring tensions.

Transmitter Contact Cleaning

Any required emery work and/or burnishing on the transmitter contacts should be performed before the spacing and tension adjustments of these contacts are made. The emery board should not be used on the contacts unless they are burned or badly pitted. Even then it should be used sparingly and carefully. Be careful not to emery down a contact so that you alter its surface angle. Move the emery board in a direc-

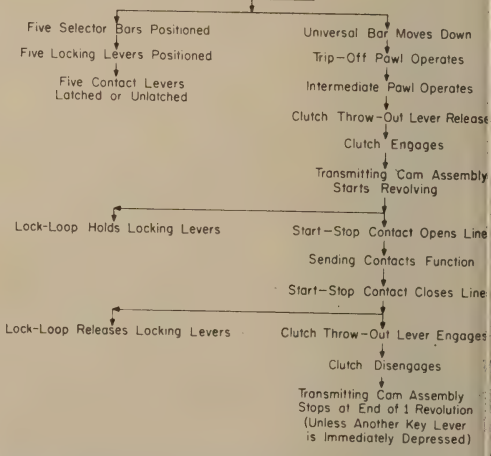

Key Lever Depressed
Five Selector Bars Positioned
Five Locking Levers Positioned
Five Contact Levers Latched or Unlatched
Universal Bar Moves Down
Trip-Off Pawl Operates
Intermediate Pawl Operates
Clutch Throw-Out Lever Release
Clutch Engages
Transmitting Cam Assembly Starts Revolving
Lock-Loop Holds Locking Levers
Start-Stop Contact Opens Line
Sending Contacts Function
Start-Stop Contact Closes Line
Lock-Loop Releases Locking Levers
Clutch Throw-Out Lever Engages
Clutch Disengages
Transmitting Cam Assembly Stops at End of 1 Revolution (Unless Another Key Lever is Immediately Depressed)

Fig. 8.14—Chart showing sequence of the keyboard functions after a key lever has been depressed.

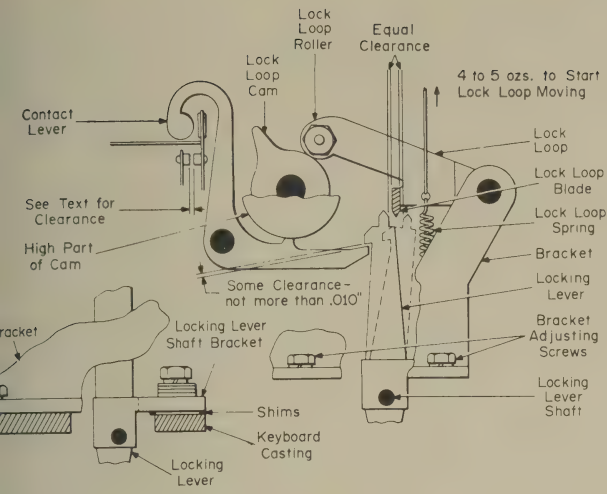


Fig. 8.15 — Transmitter contact and lock lever mechanism of a Teletype Model 15 keyboard.

on *parallel* to the plane of the contact arm t all times. Any surfaces that have had an mery board used on them should be burnished ith a burnishing tool following the emery oard use.

Lock-Loop

Figure 8.15 is a line drawing giving a simplied end view of the transmitter mechanism howing one set of contacts and associated cam, ock loop, locking lever, *etc.* One must visualze that behind this are the other duplicate ontacts and mechanisms for the other four lements for character forming, as well as that or stop-start. These details were also shown in ther figures previously. All parts in fig. 8.15 re identified and adjustable clearances are also ndicated.

Rotate the transmitting cam cylinder (See ig. 8.18) slowly by hand, in the *proper direcion*, which is *counter-clockwise* as viewed from he front of the keyboard, until the lock loop oller is resting on the low circular part of its am as shown in fig. 8.15. Hook the eight ounce pring scale in the lock loop spring hole and ull upward in opposition to the spring and in ne with the spring axis (see fig. 8.15). If the ension of the spring is proper, a pull of four to ive ounces will counteract the spring pull and tart the lock loop moving. The manufacturer tates that this spring should be replaced if its ension does not fall within these limits. (An xact replacement may not be so readily obained and a reasonable substitute can be even harder to locate.) This should be repeated for he other four character forming mechanisms hat are identical and in line with this, the front one.

Check the clearance between each contact ever and its associated locking lever when the contact lever is on the high side of its associated cam as shown in fig. 8.15. This clearance should be checked and measured while pressing firmly (not too hard) down on the locking lever. There should be a measurable clearance here under these conditions, but it should not be more than 0.010 inch. This spacing requirement can be obtained by adding or removing (in accordance with the requirement) shims between the bracket holding the five locking levers shaft and the keyboard casting. This is clearly shown and identified in fig. 8.15.

The excursion or movement of the locking levers to either side of the lock-loop blade should be the same with the alternate depressing of the LETTERS and BLANK keys. Depressing the LTRS key positions all five of the locking levers to the *right* (fig. 8.15) and depressing the BLANK key positions all of the locking levers to the *left*. The locking levers shaft bracket may be positioned laterally, under its mounting screws, to meet this requirement. Don't for-

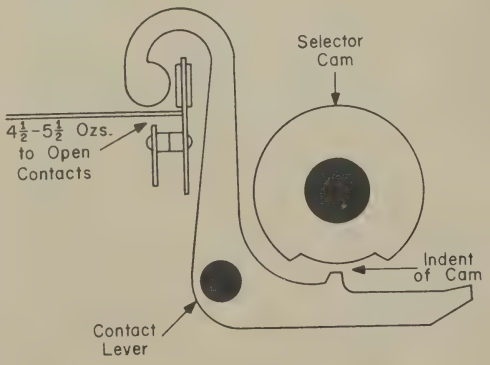


Fig. 8.16—Contact lever, selector cam and switch contacts of one of the five character element forming mechanisms shown in fig. 8.15.

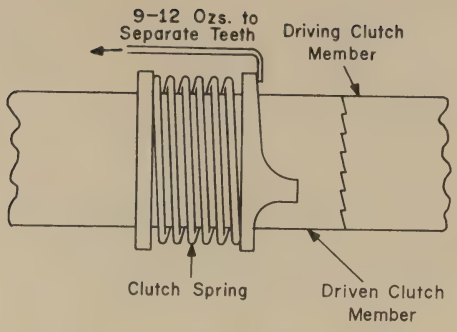


Fig. 8.17—Transmitting shaft clutch spring.

get to retighten these screws after making this adjustment.

Transmitter Contact Adjustment

After the lock-loop spring and locking lever adjustments, as outlined above, have been completed, one is ready to proceed with the adjustment of the transmitter contacts. It is assumed at this point that the instructions to clean and condition these contacts have been followed, if required.

First, check the gap spacing of each set of transmitter contacts. This spacing should be within the range of 0.020 to 0.025 inches. In each instance the gap measurement is to be made *only* when the associated contact operating lever is on the *high* part of its associated cam (see fig. 8.15). If a gap clearance is not within the specified limits, then the *shorter* contact spring, in each instance, should be bent accordingly.

We are now ready to check the spring tension of each set of transmitter contacts. This spring tension check is only to be made when the associated contact operating lever is on the *low* part of its associated cam, as shown in fig. 8.16. Each spring tension measurement must fall within the range of 4½ to 5½ ounces. In each instance, the proper indicated reading on the spring scale is the reading at the instant the contact opens. If any spring tension is not within the required limits, then the *longer* contact spring, in each case, should be bent accordingly.

It may be seen that the contact gap spacing and the contact spring tension are interrelated so that an adjustment of one may alter the other. The contact gap spacing should be rechecked each time that the contact spring tension is altered. Likewise, the spring tension should be checked each time the contact gap is altered. This may appear to be an unending circle of adjustments. It can mean several cycles of adjustments if a set of contacts happen to be considerably out of line due to rough handling or accidental bending. Generally 1½ or 2 cycles of adjustments are all that is required for each set of transmitter contacts.

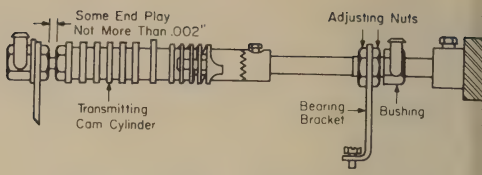


Fig. 8.18—The transmitting shaft.

Transmitting Shaft Adjustments

The transmitting shaft clutch spring tension may be checked by hooking the 32-ounce scale to the clutch-driven member edge projection and pulling directly in line with the shaft so as to compress the spring as shown in fig. 8.17. The separation of the cutch teeth should require a pull of 9 to 12 ounces. As in the case with the lock loop spring, the manufacturer recommends that the transmitting shaft clutch spring be replaced if its spring tension does not fall within the specified limits. Here again, a replacement or a substitute spring may not be easy to locate.

There should be some end play between the transmitting cam cylinder end and the rear bearing bushing as illustrated in fig. 8.18. This end play should be no more than 0.002 inches. If there is little or no end play or more than 0.002 inches, then the position of the *rear* bearing bushing in its mounting bracket should be altered accordingly by turning the adjusting nuts. The rear bearing and associated adjusting nuts are to be seen in the right hand side of fig. 8.18.

Clutch Teeth Spacing

The clearance between the clutch teeth should be between 0.005 and 0.0150 inches when the clutch is in its fully disengaged position. This position of the clutch is shown in fig. 8.19. If the clutch clearance is not within the above specified limits its position should be altered by adding or removing shims between the bracket and throw-out lever post as indicated in fig. 8.19.

It is desirable that the universal bar (fig. 8.19) have a small amount of end play but no more than 0.010 inches. The universal bar extension should be positioned approximately in the center of the space between the P and CAR RET key levers. The universal bar may be positioned to meet this requirement by loosening each pilot screw locknut and turning the pilot screws as required. This operation can best be visualized by referring back to fig. 8.2, a detailed view of the bottom of the keyboard, where the two pilot screws, #2, are shown. Be sure to retighten the two locknuts after this operation is performed.

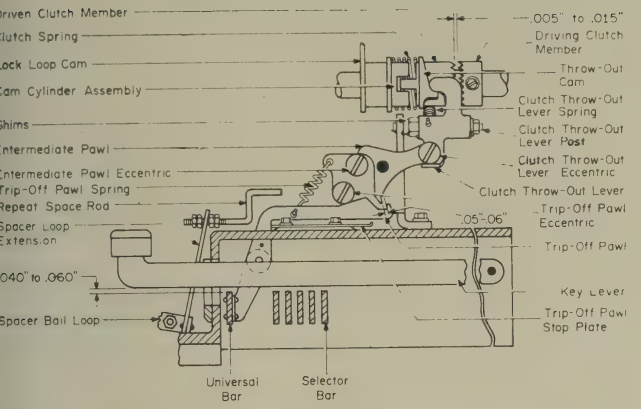


Fig. 8.19—Line drawing of a cross-section of a portion of the teletypewriter keyboard showing the clutch release mechanism and other parts associated with the transmitter. Various spacing adjustments are also shown.

The trip-off pawl should clear the sides of the stop-plate mounting screws, as well as the locking-lever bracket. This can be checked by depressing a key lever to operate the trip-off pawl.

The clearance between each of the key levers and the universal bar should be between 0.040 and 0.060 inches when the trip-off pawl is resting against the end of its stop plate. (See fig. 8.19.) This spacing may be changed by altering the position of the trip-off pawl stop plate. The stop plate has *slotted* mounting holes allowing for its movement. Its mounting screws should be retightened if it is found necessary to alter the position of stop plate.

Intermediate Pawl Eccentric

The clearance between ends of the trip-off pawl and the intermediate pawl should be between 0.050 and 0.060 inches, as shown in fig. 8.19, when the intermediate pawl rests against its eccentric and the trip-off pawl rests against the end of its stop plate. This clearance may be altered to fall within the required tolerance range by adjusting the *intermediate pawl eccentric*. This is done by first loosening the locknut and then turning the eccentric screw as required. The locknut should be retightened. Inspection of fig. 8.19 indicates that two positions of the eccentric screw satisfy the above spacing requirement. Choose the setting where the *high* part of the eccentric is towards the rear of the keyboard. (To the right in fig. 8.19.)

Clutch Throw-Out Lever Eccentric

The clutch throw-out lever eccentric should be positioned so that the intermediate pawl is held firmly between it and the intermediate-pawl eccentric when the clutch throw-out lever is resting on the *low* part of the clutch-driven member as illustrated in fig. 8.19. This eccentric screw is adjusted *after* its locknut has been loosened. This eccentric also has two positions that satisfy the above requirements. As in the other case, the position should be chosen where the *high* part of the eccentric is towards the rear of the keyboard.

Trip-Off Pawl Eccentric

Figure 8.20 shows a close-up view of the keyboard trip-off pawl, intermediate pawl, clutch throw-out lever, their associated eccentrics and other related parts. The clearance between the end of the trip-off pawl and the end of the intermediate pawl should be approximately 0.004 inches when the clutch throw-out lever is held against both the high part of its *cam* and its *eccentric*. This spacing can be altered by adjusting the trip-off pawl eccentric.

When the trip-off pawl is in its *operated position* the clearance between its lower edge and

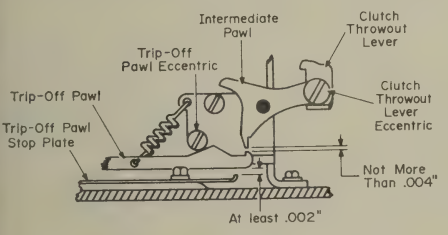


Fig. 8.20 — Details of a keyboard trip-off pawl, intermediate pawl, various eccentric screws and associated parts.

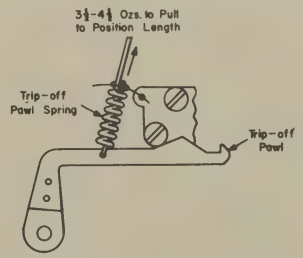


Fig. 8.21—Trip-off pawl spring tension measurement.

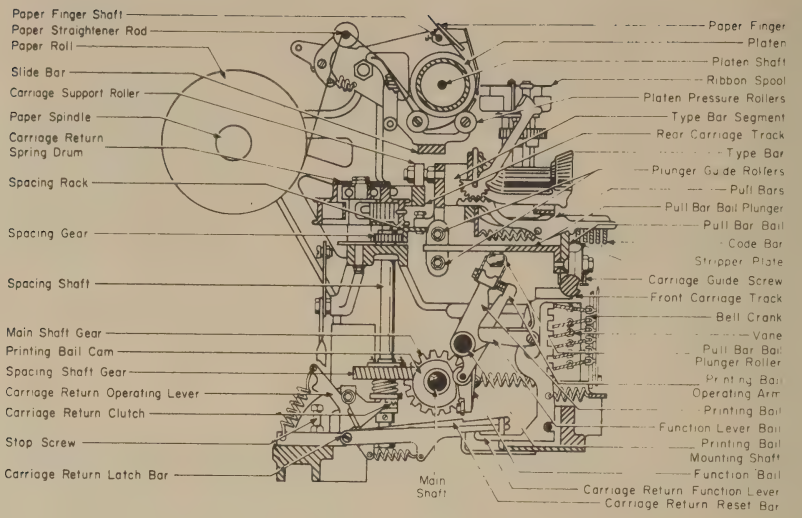


Fig. 8.22—End view of the typing unit showing the location and identity of many parts.

the formed-up end of the stop plate should be about 0.002 inches. This portion of the stop plate may be bent accordingly, in order to meet this spacing requirement.

Clutch Throw-Out Lever Spring

One end of the clutch throw-out lever spring is barely visible in the upper part of fig. 8.19. The rest of this spring is hidden from view behind the driven clutch member. Tension of this spring is measured under the following conditions: (1) Clutch teeth engaged (2) Clutch throw-out lever resting against the lower part of the clutch-driven member, (3) The intermediate pawl being held against its eccentric by the operator, (4) An 8-ounce scale hooked over the throw-out lever just above the spring hole and the operator pulling in line with the spring. The throw-out lever should start to move with a scale reading ranging from 1½ to 2½ ounces. The manufacturer recommends that the old spring be replaced with a new one if its tension fails to fall within the above range.

Trip-Off Pawl Spring

The "anchor end" of the trip-off pawl spring must be unhooked in order to measure its spring tension, as shown in fig. 8.21. An 8-ounce scale is hooked in the spring eye. In pulling on the spring its position should be kept as close to its anchor position as possible, as the tension measurement should be read when the spring is stretched to its normal position length. The tension under these circumstances should be between 3½ to 4½ ounces. The manufacturer recommends that a spring that does not fall within this range should be replaced.

Teletypewriter Units

It has been pointed out that the teletypewriter is made up of three major units. These three units are: (a) motor, (b) keyboard, and (c) typing unit. When the motor is turned on, power is available to both the keyboard and the typing unit transmitted through the main drive shaft and clutch for each respective unit. All of the units of the machine may or may not be in operation while sending whereas the keyboard is naturally not in use for receiving. It is possible to use only the motor and keyboard of the sending machine if the operator does not desire to make a copy of what he is sending. The various parts of the keyboard mechanism have just been covered. A word about the motor unit before we move on to the typing unit and its various mechanisms.

Teletype Motors

Perhaps the most important thing to remember about the motor that powers the teletype machine is that it must operate at a predetermined speed. In some of the older machines the motors were designed to operate from a power source that was either d.c. or a.c. This required the use of a governor to regulate the speed of the motor, which in turn, meant that the speed of the teletypewriter was regulated. It is required that all teletypewriter machines in a system operate at the same speed. This meant that some means of keeping the various

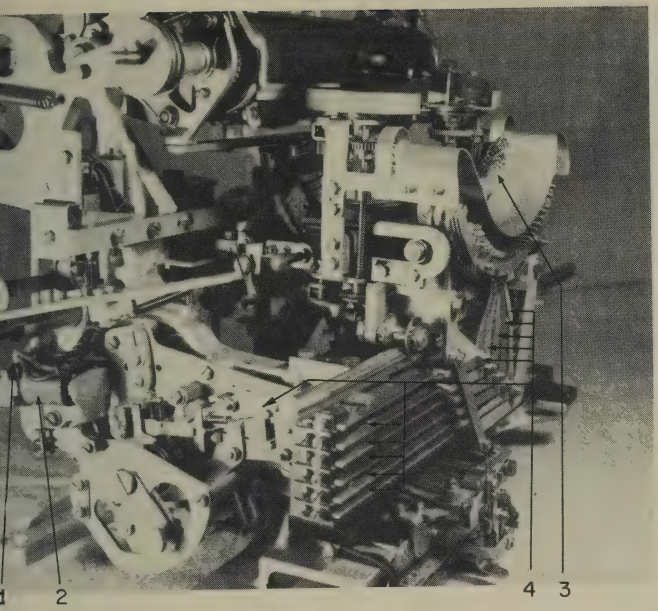


Fig. 8.23—Pictorial view of the typing unit with the receiving unit in the foreground showing its three principal functional sections.

1. Impulse input point.
2. Selector magnet.
3. Printing mechanism.
4. Selecting parts.

machines operating in synchronization had to be used; otherwise, this too would be a source of printing errors. This led to the use of synchronous a.c. motors to drive teletype machines since such an electric motor operates at a speed determined by its construction and the frequency of the a.c. power line. Later Teletype Corporation machines are equipped with 110v. 60 cycle a.c. synchronous electric motors. These are fractional horsepower motors(1/40 h.p. to 1/25 h.p. in many instances).

Typing Unit

The typing unit includes all of the mechanisms required to convert the code impulses into a typewritten page-form message, such as in the Teletype Model 15 and Model 19 and on tape in the instance of the Teletype Model 14 typing reperforator. All mechanically operated parts of the typing unit receive their driving power from the mainshaft assembly which is directly connected through the mainshaft gear to the pinion located on the end of the motor shaft. As long as the motor is running, power is immediately available through the various clutches, cams, and gears to move and rotate the various parts of the typing unit at the speed required to synchronize their action with the code impulses received by the selector magnet. The selector magnet through the associated selecting mechanism determines whether one of the type bars is to be thrown against the platen causing a character or symbol to be printed or one of the functions listed below to be completed.

1—Platen line feeds.
2—Typing Carriage spaces.
3—Typing Carriage returns.
4—Platen shifts from letters to figures.
5—Platen unshifts from figures to letters.
6—Blank.
7—Signal bell operates.
8—Mechanical motor stop opens.

Figure 8.22, a detailed line-drawing of the end view of the typing unit, is included at this point as an excellent reference since it identifies so many of the parts. With a close inspection of this figure, one can note familiar names of parts and mechanisms already covered. At the same time one will discover other parts that have not yet come under discussion up to this point. These figures should give the uninitiated a wealth of information on all of the innards of the teletypewriter.

Receiving Mechanism

The receiving mechanism is shown in the forefront in fig. 8.23. It should be readily recognized that the *receiving mechanism*, as pictured in fig. 8.23 is a portion of the typing unit shown also in fig. 8.22 and various other figures throughout the text. The receiving mechanism consists of three basic units. These units are (a) Selector magnet (b) Selecting parts and (c) Printing mechanism as labeled in fig. 8.23. One should compare fig. 8.23 with fig. 8.22 and other figures showing details of the typing unit to see how the receiving mechanism and other parts of the typing unit function together.

The sequence of operation is in the same order in which they are listed here. The selector magnet in the receiving mechanism is controlled by the code impulses received from a transmitting mechanism and translates them

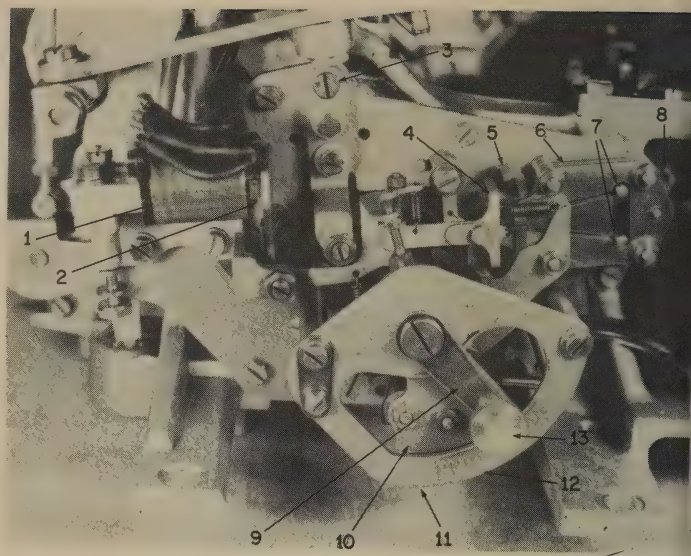


Fig. 8.24 — The selector unit of the Model 15 with the important parts identified.

1. Magnet.
2. Armature.
3. Eccentric screw.
4. Armature extension.
5. Sword arms.
6. Selector separator plates
7. Stop posts.
8. Selector T-Levers.
9. Range Finder adjustable arm.
10. Stop lever bracket.
11. Ranger finder assembly.
12. Scale.
13. Thumb screw.

into related mechanical movements of certain parts. These are the parts labeled "selecting parts" in fig. 8.23. The selection of a particular combination of positions for these parts determines the *character to be printed* or the *function* (such as carriage return or line feed) to be completed by the typing unit of the teletypewriter.

Selector Unit

The selector unit is, first, a part of the typing unit as pointed out earlier. Secondly, to pinpoint it further, it is a part of the receiving unit of the typing unit as illustrated in fig. 8.23. Figure 8.24 shows a detailed view of the selector unit with some of the parts identified. Basically, the selector unit is composed of a *d.c. operated electromagnet,* called the selector magnet, and an associated ingenious mechanism. The mechanism will be covered in due course. The selector magnet has a reliable and fast acting armature that faithfully follows (when properly adjusted) the coded impulses that are received by the selector magnet coil. Figure 2.15 shows the location of this unit on the left side of a Teletype Model 15 receiving mechanism and fig. 2.20 shows a closeup view of the selector unit of a Teletype Model 14 typing reperforator. The next several figures will show various mechanical details of the selector mechanism of a Model 15 teletype machine. Do not be surprised or concerned if there is a slight difference between some of the illustrations and your Model 15 as there are variances here and there, depending upon the vintage of the machine.

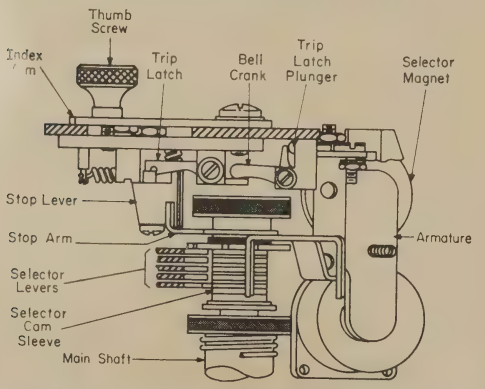


Fig. 8.25—Cross section of the selector unit from the Model 15, identifying the various parts.

A cross-sectional view of the selector unit is shown in fig. 8.25 and a side view is shown in fig. 8.26. The details of the locking lever operation are given in fig. 8.27. A sequence chart outlining the operation of the selecting mechanism is given in fig. 8.28. This chart should also be helpful in studying the various figures. Figure 8.29 gives details of the typing unit clutch.

The selector unit (figs. 8.24 to 8.27) is located on the left end of the typing unit (fig. 2.15) and consists of a selector magnet, a selector armature, five selector levers, five swords, five T-levers, a selector mounting plate with posts and springs, and the range finder assembly. The selector mechanism is designed to translate the marking (current) and spacing (no-current) impulses, received from the line, into a series of mechanical motions which will cause the vanes on the front of the typing unit to be positioned in accordance with the *character* or *function* assigned to each *combination of five selecting impulses.*

The selector mechanism is controlled by the armature of the selector magnet which receives

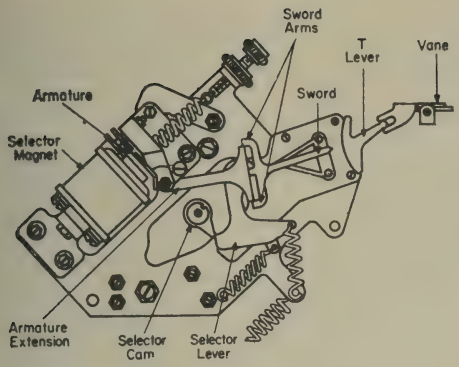


Fig. 8.26—Side view of the selector unit from the Model 15, identifying the various parts.

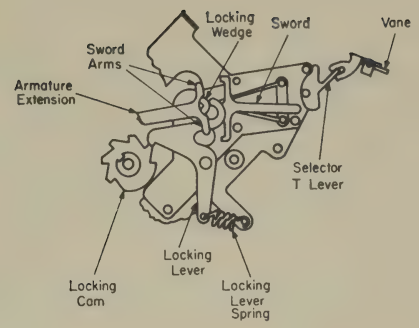


Fig. 8.27—Details of the locking lever from the selector unit.

the code impulses from the line. As shown in fig. 8.25, the armature of this magnet is normally pulled up and the stop arm is against the stop lever which in turn is held by the trip latch. Because the stop arm, which is a part of selector cam sleeve, is engaged with the stop lever, the cam sleeve does not revolve.

When a start impulse, which is spacing (no-current), is received, the armature is released and pulled away from the magnet pole pieces by the armature spring. The trip latch is moved out of engagement with the stop lever, releasing the stop arm, and allowing the cam sleeve to revolve with the shaft. Each of the vanes in turn is operated by a selector cam through a T-lever, a sword, and a selector lever. (See fig. 8.26.)

As an example of how the selector unit operates, assume that the code for the letter E is received. Upon the reception of the start impulse (no-current impulse), the armature moves away from the magnet and pushes the trip-latch plunger (fig. 8.25), which causes the trip-latch bell crank to move the trip-latch out of engagement with the stop lever, releasing the stop arm. The selector cams start to revolve and the No. 1 selector cam engages No. 1 selector lever, when the first impulse (marking or current) of the letter E has been received from the line. The magnet armature is pulled up, bringing the upper end of the armature extension up into the path of the upper sword arm. When the No. 1 cam engages the No. 1 selector lever, this lever is turned counterclockwise, carrying with it the sword which strikes the upper end of the armature extension and is turned clockwise about its pivot. (See fig. 8.26, point A.) The sword is then positioned so that when the No. 1 cam clears the selector lever, the selector lever spring moves the sword against the T-lever and brings the front edge of the No. 1 *vane down*. Since no current is received while Nos. 2, 3, 4, and 5 cams are engaging their selector lever, the magnet armature is released and the armature extension moves down so that the lower end of the armature is in the path of the lower sword arm. (See fig. 8.26.) As the Nos. 2, 3, 4, and 5 cams engage the Nos. 2, 3, 4, and 5 selector levers the, Nos. 2, 3, 4, and 5 vanes are moved so that the front edges are *up*. With the front edges of the vanes up, the corresponding *code bars are moved right* by the connecting bell cranks to *the unoperated position*. With the front edges of the vanes in lower position, the corresponding *code bars are moved left to the operated position*. With the No. 1 code bar to the *left*, and Nos. 2, 3, 4, and 5 code bars to the right, one notch in each code bar is *opposite the E pull bar*. The sixth cam (fig. 8.29), releases the mainshaft clutch, allowing the printing bail and function bail to make *one complete revolution*. The printing bail cam permits the printing bail to be pulled forward by its spring. The E pull bar pulled down by its spring into the path set up by the code bars, and the pull-bar bail moved by the printing bail, carries the pull bar forward, causing the type bar to strike the platen, printing the letter E. All of this happens in just about the time it takes to bat an eyelash—163 milliseconds, in fact, at 60 w.p.m.

The operations of the selector unit in forming other characters is essentially the same, except for the coded sequence or order in which the character-forming parts operate. In addition to the characters or symbols, as determined by the type pallets, that can be received and printed, there are the eight *functions*, such as typing carriage return and line feed to be performed from the operations of the selector unit. These eight specific functions were listed under the "Typing Unit" section earlier in the text. Here again the operations of the selector unit are essentially the same, except for the order in which the intelligence-giving parts operate.

Locking Cam and Locking Lever

The locking cam has five high and five low portions on its periphery against which the locking lever is held by its spring. (See fig. 8.27.) The purpose of the cam and locking lever is to hold the armature extension arms firmly in position while the swords are being positioned by striking the armature extension arms.

During that part of each code impulse when the swords are being positioned by striking the armature extension arms (at the time when any cam is operating the corresponding selector lever), a low portion of the locking cam is in contact with the locking lever. The armature extension is then held firmly in position by the U-shaped extension of the locking lever engaging the locking wedge on the armature extension. When the locking lever is riding on the high portion of the locking cam, the locking-lever extension is held away from the locking-wedge and the armature is free to move in response to the impulse being received.

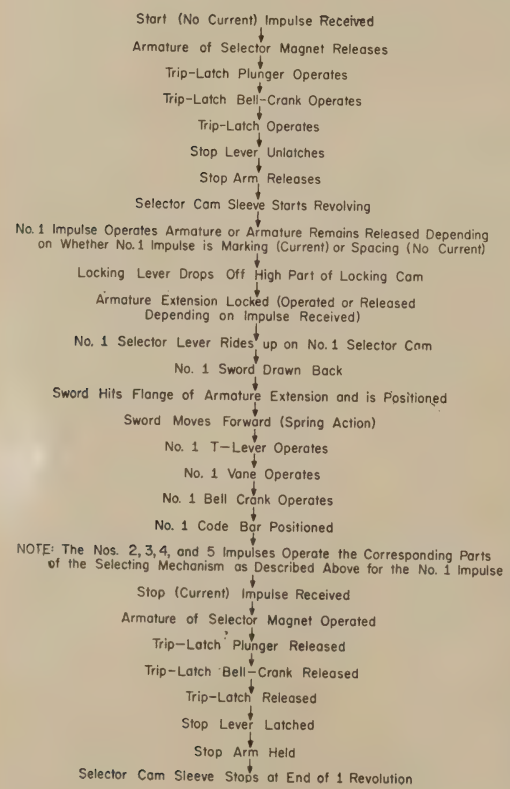

Start (No Current) Impulse Received
Armature of Selector Magnet Releases
Trip-Latch Plunger Operates
Trip-Latch Bell-Crank Operates
Trip-Latch Operates
Stop Lever Unlatches
Stop Arm Releases
Selector Cam Sleeve Starts Revolving
No. 1 Impulse Operates Armature or Armature Remains Released Depending on Whether No. 1 Impulse is Marking (Current) or Spacing (No Current)
Locking Lever Drops Off High Part of Locking Cam
Armature Extension Locked (Operated or Released Depending on Impulse Received)
No. 1 Selector Lever Rides up on No. 1 Selector Cam
No. 1 Sword Drawn Back
Sword Hits Flange of Armature Extension and is Positioned
Sword Moves Forward (Spring Action)
No. 1 T-Lever Operates
No. 1 Vane Operates
No. 1 Bell Crank Operates
No. 1 Code Bar Positioned
NOTE: The Nos. 2, 3, 4, and 5 Impulses Operate the Corresponding Parts of the Selecting Mechanism as Described Above for the No. 1 Impulse
Stop (Current) Impulse Received
Armature of Selector Magnet Operated
Trip-Latch Plunger Released
Trip-Latch Bell-Crank Released
Trip-Latch Released
Stop Lever Latched
Stop Arm Held
Selector Cam Sleeve Stops at End of 1 Revolution

Fig. 8.28—Sequence chart outlining the operation of the selecting mechanism.

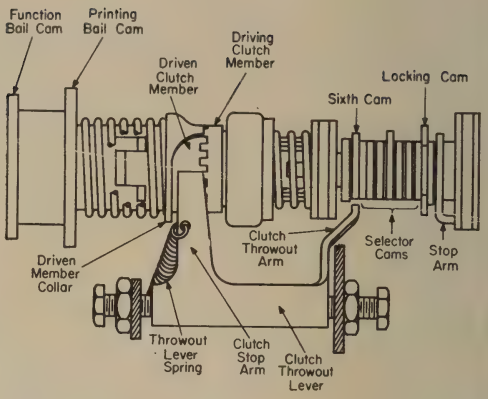


Fig. 8.29 — Crossection of the main shaft showing the typing unit clutch.

Main Shaft Clutch Throw-Out Lever

The main-shaft clutch throw-out lever (fig. 8.29) consists of the clutch-stop arm, throw-out lever spring, and throw-out arm. It is designed so that the extension of the clutch-stop arm rides on the driven clutch member of the main shaft and the throw-out arm rides on the sixth cam. The clutch throw-out lever cams the driven clutch member out of engagement with the driving clutch member. After camming the driven member out of engagement with the driving member it blocks the rotation of the printing and function-bail cams until all five impulses have been received by the selector mechanism. This insures that printing or function will not be performed before all the impulses are received.

The sixth cam on the selector cam sleeve releases the main-shaft clutch, allowing the printing and function-bail cams to make one complete revolution (See fig. 8.29.) At the end of each revolution of the printing and function-bail cams, the clutch-stop arm engages the cam surface on the driven clutch member and moves it out of mesh with the driving clutch member. Immediately after the fifth impulse has been received, and just as the fifth selector lever is sliding down from the peak of its cam, the peak of the sixth cam strikes the clutch throw-out arm and moves the clutch-stop arm out of engagement with the projection on the driven clutch member. The spring then moves the driven clutch member into mesh with the driving member. Immediately after the completion of the selection of any character or function, the printing and function-bail cams (fig. 8.29) turn one revolution, which causes the printing of that character or the operation of that function.

Any character or function may be selected while the printing of the previous selection is taking place.

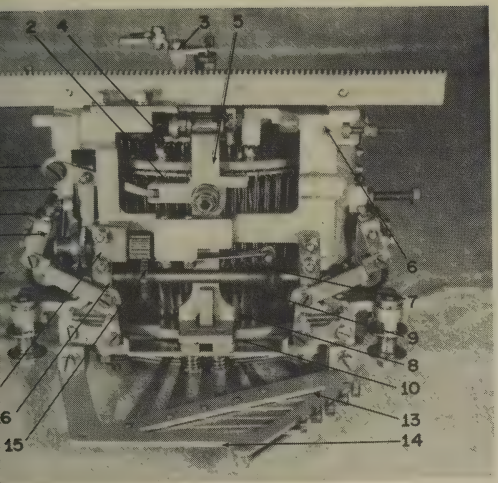


Fig. 8.30—Bottom view of the type-bar carriage with the major parts identified.

1. Spacing rack.
2. Plunger roller.
3. Carriage support roller.
4. Pull bar bail plunger.
5. Left plunger arm.
6. Right margin adjusting screw.
7. Detent.
8. Pull bar bail.
9. Ribbon reverse pawl.
10. Ribbon reverse bail.
11. Carriage support roller.
12. Carriage guide screw.
13. Bell crank.
14. Bracket.
15. Ribbon feed shaft.
16. Ribbon feed shaft gear.
17. Bevel gear.
18. Vertical ribbon feed shaft.
19. Ribbon feed rachet gear.
20. Ribbon feed ratchet.
21. Ribbon reverse shaft.
22. Ribbon feed pawl.
23. Feed lever.

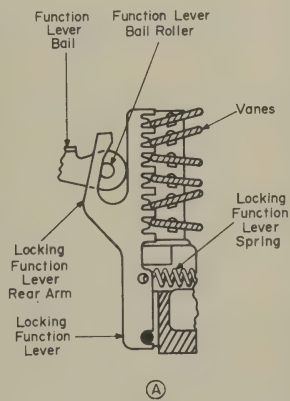
The operations of the selector unit, locking cam and locking lever and mainshaft clutch throw-out lever should be thoroughly studied by the reader. These operations should be followed by viewing the parts in the associated figures, visualizing each operation. Continued reference to the sequence chart (fig. 8.28) should also be made while making these observations.

Type Bar Carriage Printing Mechanism

The printing mechanism on the type bar carriage consists essentially of a pull-bar bail, pull bars, type bars, and necessary mounting parts. The actual printing is done mechanically, that is, the type bars are thrown at the platen by the pull-bar bail. Located between the printing bail blades (when the type-bar carriage is mounted in place) is a plunger roller (fig. 8.30) which extends downward from the pull-bar bail plunger. Thus the movement of the printing bail applies a reciprocating motion to the pull-bar bail for the purpose of actuating the pull bars.

The type bar to be selected is determined by the setting of the five code bars, which are moved into position by the bell cranks (fig. 8.30) under the control of the vanes. The code bars are so arranged that notches on their upper sides will be lined up, permitting the selected pull bar to move down into the path of the pull-bar bail. As the pull-bar bail moves forward it will allow all pull bars to rest on the code bars under the tension of the pull-bar springs. The selected pull bar will drop into the notch set up for it in the code bars, which will position it lower, with respect to the bail, than the other pull bars. As the pull-bar bail continues on its forward stroke, it will engage a notch on the selected pull bar, but will clear all unselected pull bars.

The forward movement of the selected pull bar will cause its associated type bar to strike



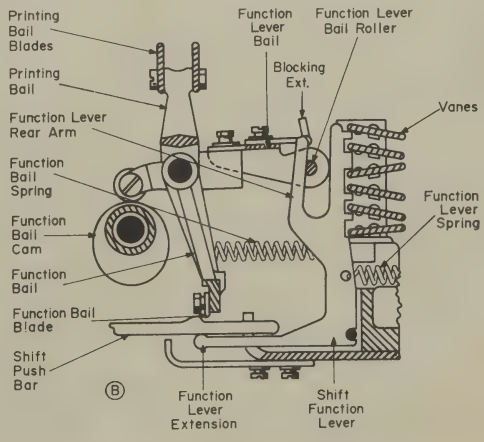


Fig. 8, 31 (A)—Locking function lever. (B) Function lever mechanism.

the platen. Before the pull-bar bail reaches the limit of its forward travel, a stripper plate (fig. 8.22), located below the pull bars, cams the selected pull bar off the bail and momentum carries the type bar against the platen. As the roller on the printing-bail arm rides to the high part of its cam to complete the printing cycle, the printing and pull-bar bails will be moved to their rear position. The pull bars will then be raised clear of the code bars so that they are free to respond to a new selection.

Locking Function Lever

The locking function lever is the first on the right of the functional levers, which are mounted behind the vanes. The locking function lever (fig. 8.31 (A) and (B)) locks or holds the vanes in the selected position until a character is printed or a function has been performed.

When the printing bail moves forward, the function-lever bail roller moves downward off the high parts of the function-lever rear arm, allowing the locking function-lever spring to pull the lever against the rear edges of the vane The locking function lever engages each vane, whether in the marking or spacing position, locking the vanes in the selected position until the printing-bail cam has revolved completely. The operation of each of the remaining function levers is dependent upon the related functions. A sequence chart for the operation of the printing mechanism is shown in fig. 8.32.

Spacing

Proper spacing between characters requires the type-bar carriage to be moved with each character printed. The type-bar carriage is moved by the spacing gear which is meshed with the spacing rack (fig. 8.33) and is facilitated by three carriage support rollers, two of

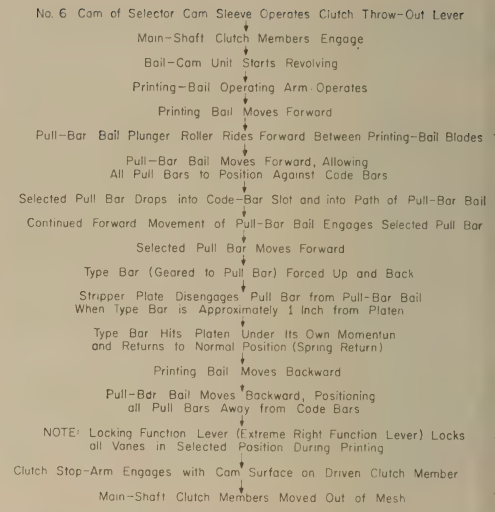

No. 6 Cam of Selector Cam Sleeve Operates Clutch Throw-Out Lever
Main-Shaft Clutch Members Engage
Bail-Cam Unit Starts Revolving
Printing-Bail Operating Arm Operates
Printing Bail Moves Forward
Pull-Bar Bail Plunger Roller Rides Forward Between Printing-Bail Blades
Pull-Bar Bail Moves Forward, Allowing All Pull Bars to Position Against Code Bars
Selected Pull Bar Drops into Code-Bar Slot and into Path of Pull-Bar Bail
Continued Forward Movement of Pull-Bar Bail Engages Selected Pull Bar
Selected Pull Bar Moves Forward
Type Bar (Geared to Pull Bar) Forced Up and Back
Stripper Plate Disengages Pull Bar from Pull-Bar Bail When Type Bar is Approximately 1 Inch from Platen
Type Bar Hits Platen Under Its Own Momentun and Returns to Normal Position (Spring Return)
Printing Bail Moves Backward
Pull-Bar Bail Moves Backward, Positioning all Pull Bars Away from Code Bars
NOTE: Locking Function Lever (Extreme Right Function Lever) Locks all Vanes in Selected Position During Printing
Clutch Stop-Arm Engages with Cam Surface on Driven Clutch Member
Main-Shaft Clutch Members Moved Out of Mesh

Fig. 8.32—Sequence chart for the printing mechanism.

which operate on the front track and one on the rear track (figs. 8.33 and 8.34). The spacing rack is mounted on the rear of the type-bar carriage casting and the pinion is attached to the upper end of the spacing shaft. The spacing shaft, extending downward, passes through the spacing shaft gear. Just above its lower bearing the spacing shaft mounts the carriage return clutch, the lower member of which is rigidly attached to the shaft. The return-clutch members are in engagement at all times except when the carriage is being returned from the end of a line. The function of the clutch will be described later. The spacing shaft gear meshes with the spacing pinion on the main shaft as previously described. Spacing is controlled from

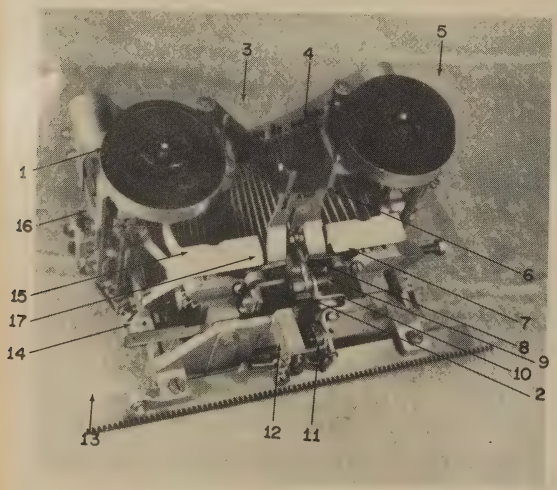


Fig. 8.33—Rear view of the type-bar carriage with all the major parts identified.

1. Code bars (under cover plate).
2. Ribbon oscillator extension.
3. Ribbon reverse arm.
4. Type bar.
5. Ribbon spool.
6. Ribbon carrier.
7. Adaptor plate.
8. Ribbon oscillator.
9. Ribbon shift lever.
10. Ribbon shift lever roller.
11. Ribbon shift lever bracket.
12. Flanged roller.
13. Spacing rack.
14. Ribbon lockout bar.
15. Type bar segment.
16. Carriage support roller.
17. Adapter plate mounting screw.

. Friction assembly set screw.
. Paper fingers.
. Platen.
. Detent ratchet.
. Paper finger shaft stop arm.
. Paper finger shaft spring.
. Platen balance spring.
. Line feed detent lever.
. Slide bar.
. Margin bell hammer stop post.
. Rear track.
. Spacing stop lever bracket.
. Printing bail blades.
. Printing bail.
. Printing bail spring.
. Front track.
17. Universal function lever ext.
18. T lever.
19. Blank function.
20. Stop bracket.
21. Intermediate lever.
22. Send-Receive reset lever.
23. Reset lever lower adj. screw.
24. Motor stop function lever.
25. Upper adj. screw.
26. Vanes.
27. Printing bail operating arm.
28. Spacing escapement pawl operating arm.
29. Dashpot lever spring.
30. Dashpot lever.
31. Carriage return spring drum.

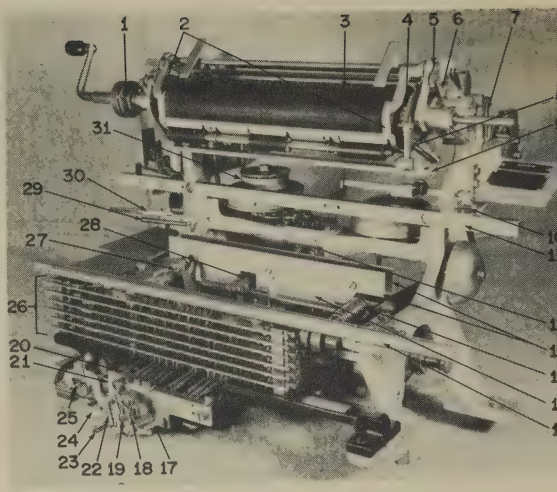


Fig. 8.34—Front view of typing unit with major parts identified.

he printing bail through the medium of the escapement pawls.

The spacing action is as follows: With the printing bail in its rear position, the rear escapement pawl is engaged with one of the teeth in the spacing escapement ratchet, thus holding the ratchet and spacing gears stationary (See fig. 8.35). As the printing bail starts to move forward, the escapement pawl operating arm strikes the lower end of the rear pawl thereby moving it out of engagement with the tooth on the escapement ratchet. At the same time the front escapement pawl moves against the ratchet and into the path of another tooth which it will engage after the ratchet has traveled one-sixth of a space. The printing operation then takes place.

Near the end of the return stroke of the printing bail, the operating arm lifts the front escapement pawl out of engagement with the escapement ratchet, and at the same time the rear pawl moves against the ratchet. This action will allow the spacing mechanism to revolve sufficiently to space the carriage five-sixths of a space at the end of which the rear escapement pawl will engage a tooth on the ratchet. The remaining one-sixth of a space will be added preceding the printing of the next character as described in the foregoing. A sequence chart for the spacing operation is shown in fig. 8.36.

When the type-bar carriage reaches the end of a line, the right margin adjusting screw (fig. 8.35) moves the spacing stop lever into the path of a projection on the spacing stop sleeve, thus blocking rotation of the spacing mechanism and preventing further spacing of the carriage.

Selecting Cycle Overlap With Printing Or Function Cycle

It was pointed out in the beginning of this text that the normal or required speed (by the F.C.C.) is 60 words per minute (368 oper. per min.) for amateur RTTY in the U.S.

Through the use of an overlap arrangement, the teletypewriter can perform a printing or function operation while the next selection is being set up on the keyboard transmitter unit, transmitted and stored in the receiving mechanism by setting the swords in the new selection order. Tension springs on the selector levers supply the energy required to complete the selection for the next printing or function oper-

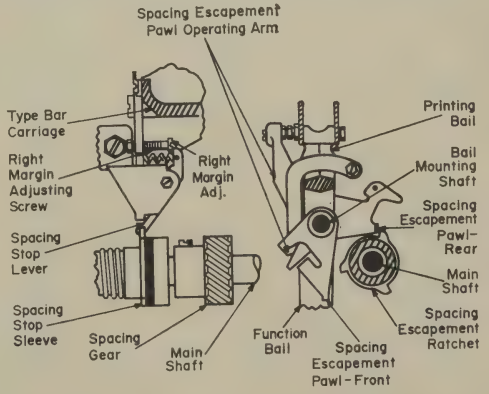


Fig. 8.35—Pictorial view of spacing stop mechanism with the major parts identified.

ation, when the mechanism is unlocked after a completed operation. The chart of fig. 8.36 shows the relationship between the operation of the previous selection and the setting up of the next selection when the teletypewriter is operating at 368 o.p.m.

Operation of Functions

There are two types of operations which can be performed by the typing unit. The first embodies those mechanical actions which are directly necessary to the actual printing of a character. The second type of operation, which embodies mechanical action supplementary to the printing of a character, or which alters the position of various mechanisms, is known as a function. Ten functions which generally are found on standard models and which may be added to as desired, are: bell, blank, carriage return, figures (shift), letters, line feed, motor stop, and space. The completion of these functions is accomplished through separate function levers located behind the vanes in the front of the typing unit.

When the printing bail is in its normal (rear) position, the function lever bail, attached to the printing bail, holds the function levers away from the vanes. As the printing bail moves forward, the function-lever bail roller moves down off the high portion of the rear arm of the function levers, permitting the function-lever springs to pull their levers against the vanes. The forward arms of the function levers are notched so that when a function combination is set up on the vanes, the selected function lever moves forward farther than the other function levers. The function lever extension then moves the selected push bar upward and into the path of the function bail.

Function Bail

The function bail is mounted on the ba mounting shaft (fig. 8.31 (B)). It is used operate some of the functions, and is mov by the function bail cam. The function bail h a blade attached to its lower extremity whi engages the function push bars.

The function-bail spring holds the functio bail cam roller against its cam at all tim After the printing bail and the function-lev bail move far enough to release the functi levers, the function-bail roller starts to ride on the high part of its cam. The function-b blade moves toward the rear, engaging and o erating any function push bar that may ha been moved into its path by the selected fun tion lever. The function-bail roller then rides the low portion of the function-bail cam, a the function-bail returns to its forward positio The bail cam unit on the main shaft has not y completed its revolution at this point, so t function-bail roller comes to rest. The roll comes to rest beyond the low part, at a poi about one-half of the distance to the high pa

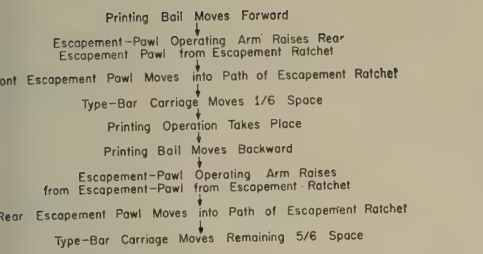
Selector Mechanism Servicing

The selector magnet, with its associate mechanism, is a remarkably accurate and re able device despite the intricate mechanical o erations that it and its associated mechanis performs. As was the case for the keyboa transmitting mechanism, there are certain a justments and maintenance requirements th the selector magnet and its associated mech nism must also be given in order for it give that remarkable accuracy and depen ability.

The selector mechanism is considerably mo intricate and extensive than the keyboa

Operation of previous selection	Locking of previous selection	Impulses of next selection	Positioning of next selection
Selector-cam sleeve stopped	Not locked	STOP	
Printing-bail and function-bail cams start to revolve—printing and function bails start moving.	Locking function lever starts forward to engage vanes.	START	Selector-cam sleeve assembly starts revolving for the next selection.
Pull-bar bail engages selected pull bar, or function bail engages a push bar.	Locked	1	Sword positioned and new selection stored.
Letter printed or function operation performed.	Locked	2	Same as above.
Printing and function bails start returning to normal position.	Locked	3	Same as above.
Printing and function bails nearly normal.	Unlocked	4	Vanes 1, 2, 3, and 4 are set simultaneously.
Printing and function bails normal —main shaft clutch throw-out lever engaged by sixth cam.	Not locked	5	No. 5 vane positioned.

Fig. 8.36—Spacing operation sequence chart. The sequences explained in each column occur in the time required to receive one selection. The third column indicates the impulses of the next selection being received and/or stored. The fourth column indicates the positioning of the next selection on the vanes, bell cranks and code bars.


Printing Bail Moves Forward
Escapement-Pawl Operating Arm Raises Rear Escapement Pawl from Escapement Ratchet
ont Escapement Pawl Moves into Path of Escapement Ratchet
Type-Bar Carriage Moves 1/6 Space
Printing Operation Takes Place
Printing Bail Moves Backward
Escapement-Pawl Operating Arm Raises from Escapement-Pawl from Escapement Ratchet
Rear Escapement Pawl Moves into Path of Escapement Ratchet
Type-Bar Carriage Moves Remaining 5/6 Space

8.37—Spacing operation sequence chart.

nsmitting mechanism. Likewise, the servicing l adjustments associated with it are more nplicated than for the keyboard mechanism. that reason, it is hoped that the reader ly mastered the data and instructions given the servicing and adjusting of the keyboard chanisms, as experience gained there will be st helpful to one when he tackles the selector chanism of his teletype machine.

Selector Lever Springs

A certain amount of dismantling must be dertaken before the selector lever springs ten- n can be checked as shown in fig. 8.38. First, nove the typing unit from the base. Next, re- ve the type-bar carriage from the typing t, and place the typing unit on its right side. ally, remove the range finder assembly from selector assembly by removing its two unting screws.

With the vanes in the marking position, turn main shaft (by hand) slowly until the ction lever bail rests on the selected letters ction lever. Move the swords (by hand) to spacing position. Hook a 32 ounce spring le over the end of each selector lever that is xt to the cam sleeve assembly (See fig. 8.38). ll the scale, in line with the selector lever, aight out from the main shaft. Each selector er should start to move when the scale pull, described above, is within the range of 6-10 nces.

Selector Separator Plates

The leaf springs (see fig. 8.39) on all of the parator plates, with the exception of the front d rear plates, should exert a light pressure on e swords. The end of each of the leaf springs ould project 0.045 to 0.055 inches below the dersurface of their straight portions, as shown fig. 8.39.

Selector Armature

The dismantling as described under section Selector Lever Springs" must be performed be- re attempting to make this check and any eeded adjustments as shown in fig. 8.40.

The armature should be free on its pivot

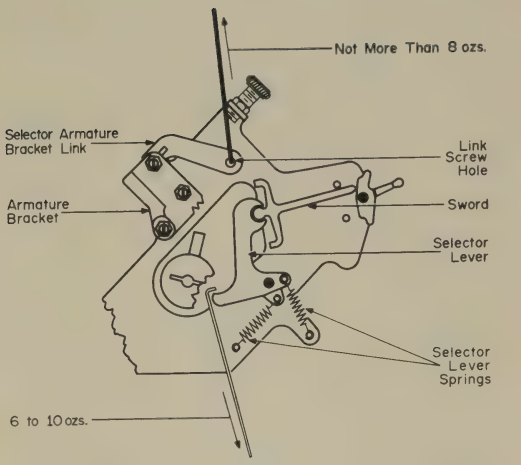


Fig. 8.38—Details of selector lever springs.

screws and the end play should be just noticeable. There should be some clearance, but not more than 0.008 inches between the No. 1 sword and the lower surface of the armature locking wedge under the following conditions:

(1) The No. 1 selector lever resting on the peak of its cam.
(2) The No. 1 sword held against the upper separator plate without bending the plate.
(3) Armature and play taken up in a direction to reduce the specified clearance to a minimum.

If there is no clearance between the armature locking wedge and the No. 1 sword, loosen the locknut on the upper pivot screw and adjust the screw to get the right clearance (a one-quarter turn of the screw is equal to about 0.006 inches). Remove the armature bracket and adjust the lower pivot screw to get the correct armature end play. Mount the armature bracket.

If clearance is more than 0.008 inches, remove the armature bracket and adjust the lower pivot screw. Mount the bracket, and adjust the armature end play by means of the upper pivot screw.

Selector Armature Bracket Link

Here again the dismantling should be per-

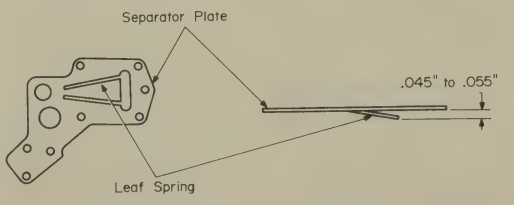


Fig. 8.39—Details of selector separator plates.

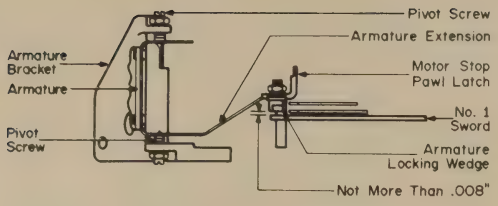


Fig. 8.40—Details of selector armature.

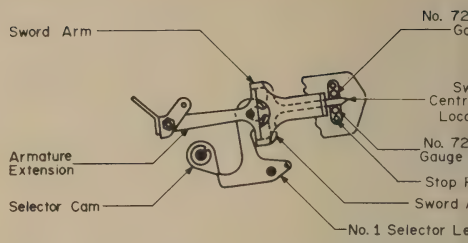


Fig. 8.41—Details for positioning sword.

formed. Refer to fig. 8.41. When the swords are held midway between the stop posts by means of the No. 72581 gauge pins, the position of the armature bracket should be such that a line through the center of the No. 1 sword extends approximately through the centers of the armature pivot screws.

Unhook the locking-lever spring, loosen the magnet bracket mounting screws, and move the bracket to its extreme rear position. Loosen the armature bracket mounting screws, loosen the link screw, and back off the armature stops. Move the bracket eccentric out of the way, so that it will not interfere with the adjustment. Turn the main shaft until the No. 1 selector lever rests on the peak of its cam. Hold the swords in a position midway between the two stop posts by means of the gauge pins inserted between the stop posts and the swords. Be sure that both armature extension arms are between the arms of the swords. With the swords held in this midway position, place the No. 73370 locating gauge over the end of the No. 1 sword, so that the two legs of the gauge are against the ends of the sword arms. Move the bracket to a position where both armature extension arms are aaginst the flat surface between the legs of the gauge. Hold the bracket in this position and tighten the link screw only. Remove the locating gauge and the two gauge pins.

Selector Armature Bracket

Remove the typing unit from the base and place the unit on its right side and refer to the details of the selector magnet and armatur mechanism as given in fig. 8.42.

The armature bracket should be in a positio which provides some clearance, but not mor than 0.040 inches, between each sword an either stop post under the following condition Turn the main shaft until the No. 1 selecto lever is resting on the peak of its cam. With th armature in its unoperated (spacing) positio move the spacing arm of the No. 1 swor against the armature extension. Place a 0.04 inch wire gauge against the spacing stop po and move the armature slowly toward th marking position. The blade of the swor should strike the 0.040 inch gauge before th armature leaves the spacing arm of the swor Under these conditions, the armature move the sword to within not more than 0.040 inche of the stop post.

Remove the 0.040 inch gauge and repeat th procedure above. The armature should leav the spacing arm of the sword before the blad of the sword strikes the spacing stop post. Un hook the armature spring at its adjusting screw With the selector armature in its operate (marking) position, move the marking arm o the No. 1 sword against the selector armatur extension. Then move the armature slowly to ward the spacing position until the armatur just leaves the marking arm of the No. sword. Check the clearance between the No. sword and the marking stop post in a simila manner. With each selector lever on the pea of its cam, the associated sword should b tried for the clearance of not more than 0.04

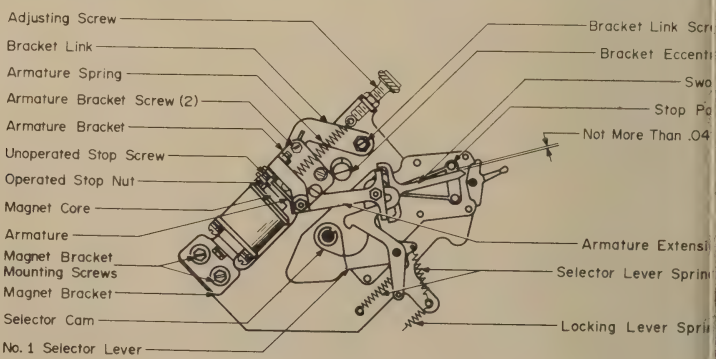
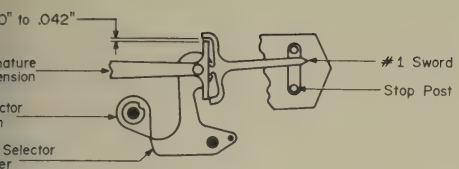


Fig. 8.42— Selector magnet and armature mechanism details.



lg. 8.43—Sword arm clearance details.

h between sword and stop post.

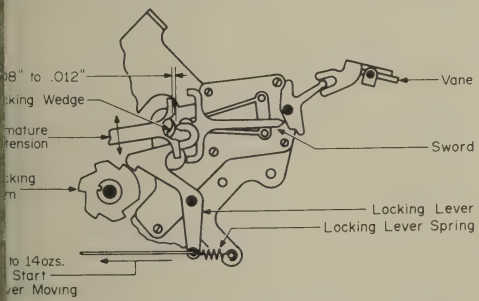
Tighten the armature bracket mounting ews just enough to allow the bracket to be ved by tapping it lightly. The clearance be- een the sword and the stop posts may be gulated by turning the bracket on its pivot. this clearance is more than 0.040 inches, ve the bracket in a direction to bring the nature toward the sword. If there is no arance, move the bracket in a direction to ng the armature away from the sword.

After the bracket is set and both screws are htened, move the bracket eccentric against the acket and tighten the screw. The position of e bracket eccentric and link, therefore, de- les the position of the bracket. The bracket ay be removed by simply removing the two acket screws. In replacing the bracket, hold it ainst the eccentric stop while the two bracket ews are tightened.

Armature Stop

Remove the typing unit from the base and ace it on its right side. Unhook the locking er spring and refer to fig. 8.43. The No. 1 ord arms (right and left) should clear the sociated arms of the selector armature exten- n 0.040 to 0.042 inches, when the front ge of the opposite sword arm is against its nature extension arm and the No. 1 selector er is on the high part of its cam. Rehook the cking-lever spring.

To adjust the right arm, reposition the nature stop screw with the armature in its operated position. (See fig. 8.42) To ad- st the left arm, reposition the armature stop



g. 8.44—This figure demonstrates the ad- stment of the armature locking wedge in making measurements as indicated.

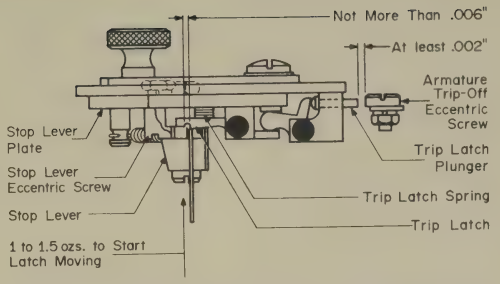


Fig. 8.46—Stop lever spring tension measurement.

nut with the armature in its operated position. If necessary, remove the nut and pinch the slotted portion to make the nut fit tight on its screw. Recheck the right arm.

Armature Locking Wedge

Again, as in the above section, remove the typing unit from the machine base and place on its right side. Unhook the locking lever spring and refer to fig. 8.44. There should be 0.008 to 0.012 inch clearance between the point of the armature locking wedge and the point of the locking lever when the locking lever is on the long, high part of the locking cam and the two points are in line. Rehook the locking lever spring. Loosen the locking wedge locknut. Move the locking wedge forward or backward in its slot in the armature extension. Tighten the locknut. When making this adjustment on typing units equipped with mechanical motor-stop mechanism, set the motor-stop pawl latch so that the shoulder of the latch is against the front face of the armature extension. (see fig. 8.40).

Stop-Lever Eccentric Screw

Remove the range finder assembly and refer to fig. 8.45. The stop lever on the range finder assembly should over-travel the latching surface of the trip latch 0.004 to 0.006 inches. Replace with a new spring, if necessary, loosening its locknut and turning the screw as required. When tightening the nut, be careful not to change the adjustment.

Stop Lever Spring

Remove the range finder assembly as in the above section and refer to fig. 8.46. With

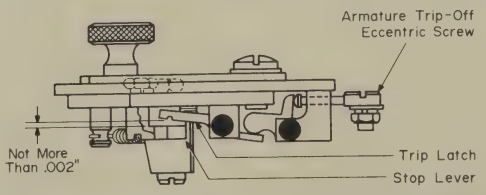


Fig. 8.45—Range finder and stop lever.

the trip latch plunger held operated, hook an 8 ounce scale at the end of the stop lever on the range finder assembly. A pull of ¾ to 1¼ ounces should be required to start the lever moving. Replace with a new spring, if necessary.

Armature Trip-Off Eccentric Screw

The requirements for the trip-off screw are as follows:

(1) There should be some clearance, (not more than 0.002 inches) between the stop lever and the trip latch when the armature is in the unoperated position and the main shaft is turned until the stopping edge of the stop lever is directly below the latching surface of the trip latch.

(2) The trip latch plunger should have at least a 0.002 inch end play (fig. 8.47) when the armature is held against the marking stop and the stop lever is clear of the latching surface of the trip latch.

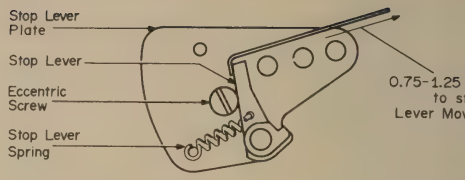


Fig. 8.47—Details of armature trip-off e centric screw adjustment.

The adjustments for the trip-off screw are follows:

(1) Position the armature trip-off eccen screw by loosening its locknut and turning screw to meet the fire requirement. (See above.) Tighten the locknut.

(2) The second requirement ((2) abo serves as a check on the trip-off eccentric sc adjustment and also on the adjustment of armature stops.

9

TAPE PRINTERS

OONER or later the more serious RTTY'er lizes the limitations of getting along with y a page printer and acquires, in addition, yping reperforator such as the Model 14. is is a nice addition to any "shack" and ds much to the flexibility and pleasure of station.

Model 14 Typing Reperforator

The Teletype Model 14 Typing Reperfora- performs the same function as a page nter, such as the Model 15 page printer t discussed, except that it prints on a con- uous length 11/16 inch wide tape instead a page wide sheet.

Obviously, if one is to have only one ma- ine, it would be more discreet to choose a ge printer, such as the Model 15, or a odel 19, if one can afford the increased pense, instead of the Model 14 tape typing d reperforator or some other tape printer. e soon discovers why if he only has a tape nter. With a single contact one can be ee deep in tape, and with one evening's eration, the shack may look like a ticker- pe parade came right through.

On the other hand, a Model 14 tape typing perforator machine can be a nice companion a page printer in an RTTY set-up. It adds uch to the flexibility of the RTTY operation. e general characteristics of the Teletype odel 14 Typing Reperforator, as well as two torial views (fig. 2.3 and 2.4) were given Chapter 2.

It will be recalled that this machine punches a chadless tape, in that the chads stay attached to the tape by a small portion of the chad edge. The machine punches the chads so that all of each chad is not quite severed from the tape. The chads are hinged to the tape, allowing them to lie fairly flat. This feature makes it possible to print over this type of perforated tape. This is a distinct advantage, as one can visually monitor or observe what is being punched on such a tape. Such tapes can be stored and referred back to without the requirement of a complicated system of identification. This, too, is an important feature, especially when one is in a hurry. Many RTTY'ers make quite an automation production of their "on the air" operations, using many pre-punched tapes to speed up operations, and to save some labor as well. One must know, at a glance, what is on a tape that is about to be put on the air.

The operator does not have an option, with the Model 14 machines, to either perforate or type on the tape. These two operations are performed simultaneously, regardless of whether one is transmitting or receiving. So far as the typing reperforator action of this machine is concerned, it is a *receiving function,* regardless of whether one is receiving or transmitting. The tape punching mechanism cannot be used as a *"reader"* to transmit a tape that has already been punched at some previous time. A Teletype Model 14 Transmitter Distributor, or similar machine, must be used

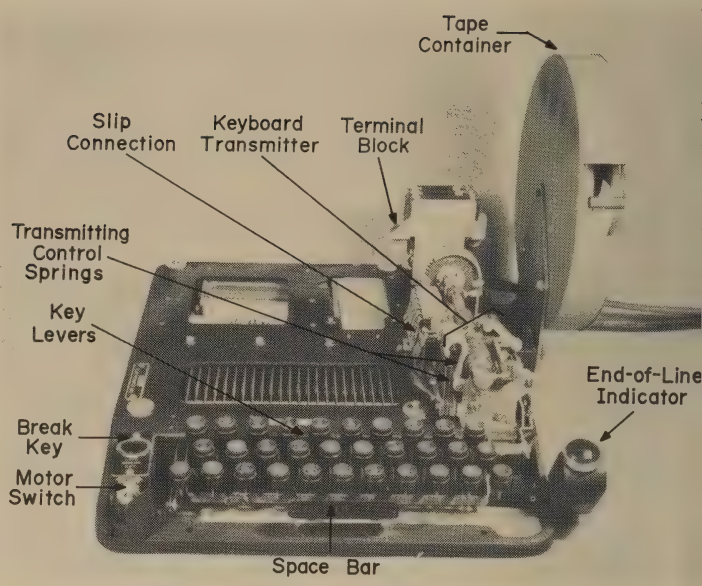


Fig. 9.1 — Sending-receiving base for Teletype Model 14 typing reperforator.

for this purpose. Such a machine is sometimes called a tape "reader." This type of machine was briefly mentioned, along with pictorial views (fig. 2.5 and 2.6) in Chapter 2.

Servicing and Lubrication

The basic requirements for servicing and lubricating a typing reperforating machine, or any other tape printer, tape reader, or other teletype machine are essentially the same as for the page printer just covered. Naturally, the actual mechanisms will vary with the machine. The next few sections apply specifically to the various mechanisms of the Teletype Model 14 Typing Reperforator.

Various figures are given to show some of the more important lubrication points, as well as the proper amount and kind of lubricant to use. The various pictorial views given were also selected so that the reader might be able to better understand the mechanical functions performed by the various mechanisms.

Model 14 Keyboard

Views of the top and bottom of the keyboard, showing lubrication points are not given here since they would not be too different from the Model 15 machine shown in figs. 8.2 and 8.3. These two illustrations should be sufficient as a guide for lubricating almost any other keyboard as well.

A top view of the keyboard is shown, however, in fig. 9.1 showing the paper tape reel on the right side, as well as the general layout of the keyboard. The reader should compare this figure to fig. 8.3 to note the similarity of the Model 14 and Model 15 keyboards.

Motors

Figure 9.2 gives a general view of the Te type Model 14 typing reperforator machi complete, except for cover. It will be no that this particular machine is supplied with synchronous type electric motor. Many these machines, especially the earlier on were supplied with electric motors requiri governor type speed controls since they we non-synchronous type electric motors. It is r too difficult to obtain the synchronous ty motors on the surplus market at a fair pri Governors that have seen years of hard se ice can get pretty stubborn at times. If it b comes too difficult to keep a governor co trolled electric motor adjusted at the rig speed, one should certainly consider replaci it with one of the synchronous, constant spe types as shown here. A word of caution is order. These motors and drive shaft wor gear vary in physical size so be sure th any new motor you get is a proper replac ment.

Model 14 Receiving Unit

A general view of the Teletype Model typing reperforator receiving unit was show in fig. 9.2 with some of the basic par identified. The basic units of a receivi mechanism are: (1) Selector magnet, (2) S lecting parts, (3) Printing mechanism, ar (4) Perforating mechanism. These four bas units of the receiving mechanism are show and identified in figs. 9.2 and 9.3. Details operation will be covered shortly.

Lubrication Points

The right side of a Teletype Model 14 ty

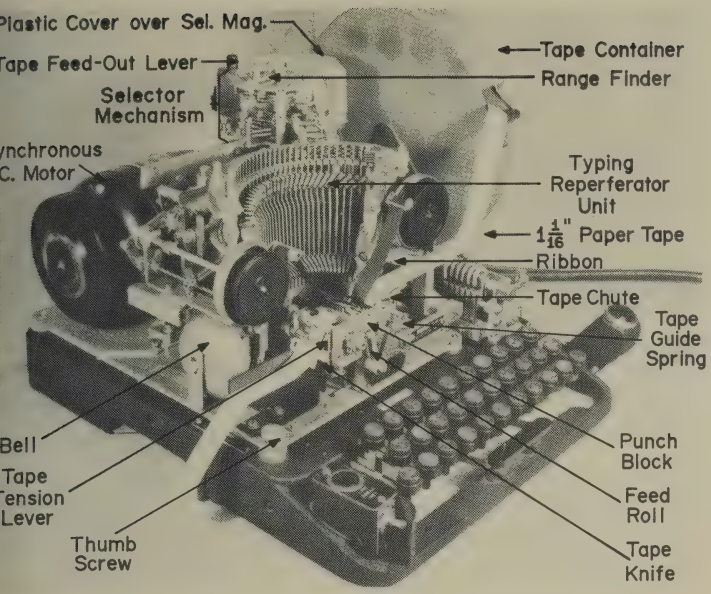


Fig. 9.2 — Teletype Model 14 typing reperforator machine, complete, except for cover.

g reperforator unit is shown in fig. 9.4. It ill be noted that the unit is minus the base ntaining the keyboard and its associated echanism and the paper tape container that mounted to the right-hand side of the base. will also be noted that the electric motor, hich mounts on the rear (right side of this cture) of the typing unit, is not in place this view of the unit. Principal lubrication ints are also shown.

A close-up view of the paper tape perforat-g mechanism is shown in fig. 9.5 indicating e more important lubrication points.

Figure 9.6 gives an excellent view of the ft side of the typing reperforator unit along ith an identification of the more important brication points.

Additional Lubrication Points

Much of the mechanical details of construc-on of the typing reperforator may be seen the rear view of this unit shown in fig. 7. The synchronous electric motor, which s on the front foreground of this view of e unit, has been removed to provide a better ew of the other parts of the unit. Numerous brication points are also identified. Excellent ews of the Model 14 mechanisms are shown the partial top and front views (fig. 9.8 d 9.9) and give additional lubrication points.

Selecting Mechanisms

The typing reperforator may be equipped ith one of two types of selecting mechanisms, e *pulling magnet* selector or the *holding agnet* selector. A quick way to ascertain hich type of magnet selector is supplied with the typing reperforator is to check the armature of the selector. If the selector is constructed so that one end of a large spring is attached to the armature and the other end is anchored to an adjusting screw, the selector supplied is a *pulling magnet selector.* The *holding magnet selector* does not have an armature spring.

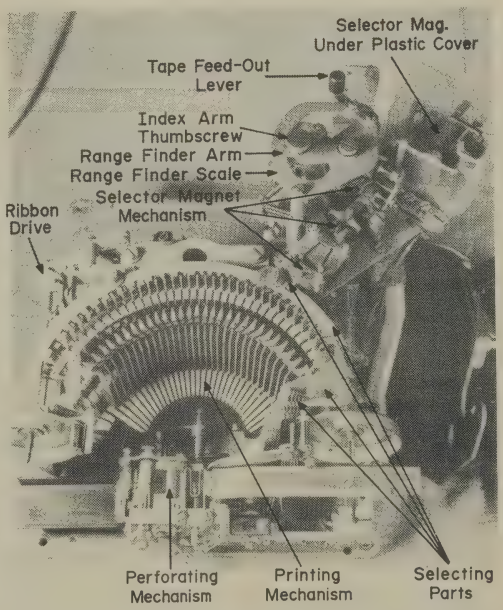


Fig. 9.3—Teletype Model 14 receiving mechanism.

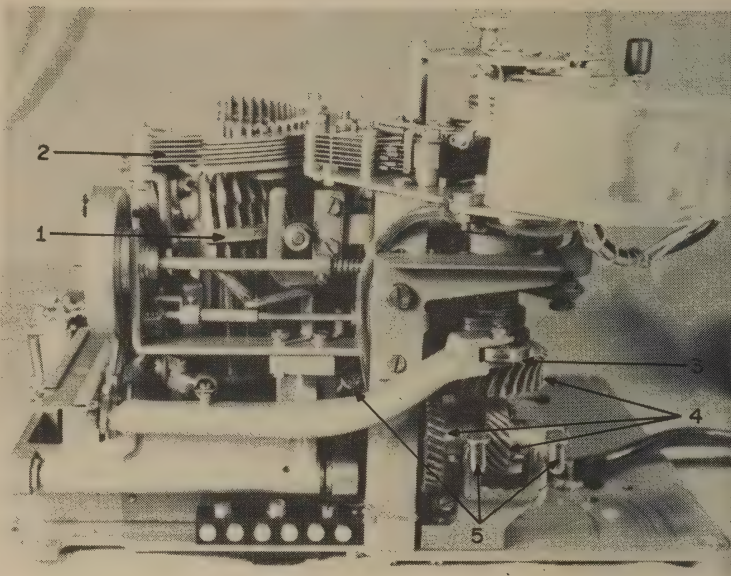


Fig. 9.4—Lubrication points on right side of Teletype Model 14 typing reperforator unit. Points marked *A* receive 1 or 2 drops of SAE 10 and those marked *B* receive Lubriplate No. 630-AA.

1. Code-bar locking lever at point of contact with main bail.	B[2]
2. Code-bar bell cranks on wearing surfaces.	A
3. Punch-arm casting roller.	B[2]
4. Drive gears.	B[2]
5. Bearings.	A[1]

[1]Fill cups.
[2]Sparingly.

It can readily be seen that more magnetic force is required to pull a "loaded" armature to a magnet's face than is required to hold the armature once it is against the face of the magnet. All other things being equal, this would indicate a preference for a "holding type" magnet arrangement in the selector magnet instead of a "pulling type" magnet arrangement. The detailed functioning of each type of selector is discussed below.

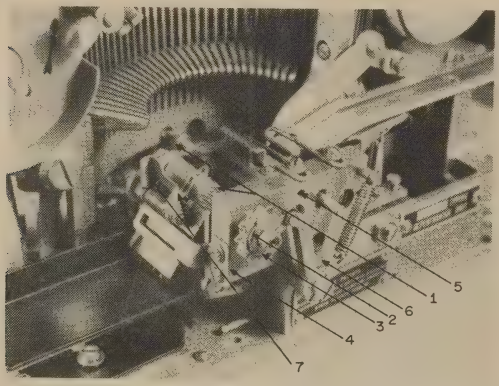


Fig. 9.5—Lubrication points for tape perforating mechanism of Model 14 Machine. Points marked *A* receive 1 or 2 drops of SAE10 and those marked *B* receive Lubriplate No. 630-AA.

1. Feed-roll bearing, 2 places	A
2. Star wheel.	B[1]
3. Punch bars at punch-bail guide comb.	A
4. Feed-pawl bearing.	A
5. Feed-roll roller.	A
6. Feed-roll detent bearing.	A
7. Tape tension lever.	A

[1]Sparingly.

Pulling Magnet Selector Unit

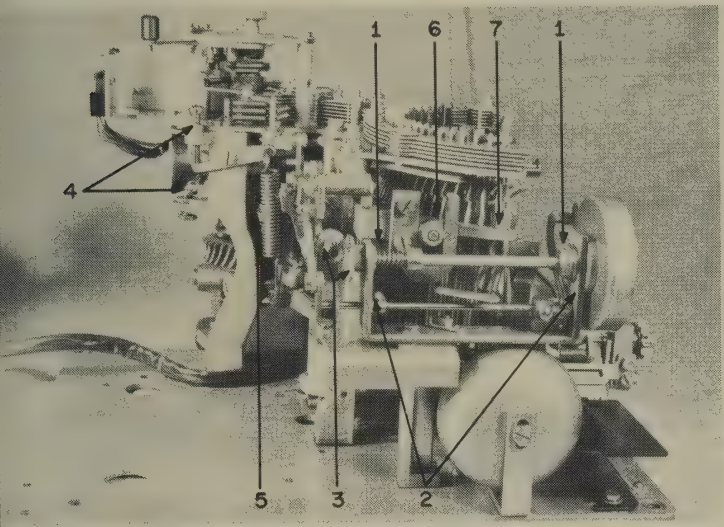
The selector unit located on the top right side of the typing reperforator unit (figs. 9.10 to 9.13) consists of a selector magnet, a selector armature (with armature springs), five selector levers, five swords, five T-levers, a selector mounting plate with posts and springs and the rangefinder assembly. The selector mechanism is designed to translate the marking (current) and spacing (no-current) impulses received from the line into mechanical motion which causes the code bars on the top of the type basket to be positioned in accordance with the character or function assigned to each combination of five selecting impulses. The selector mechanism is controlled by the armature of the selector magnet which receives the electrical code impulses from the line. Normally, the armature of this magnet is pulled up and the stop arm is against the stop lever which in turn is held by the trip latch. Because the stop arm which is a part of the selector-cam sleeve is engaged with the stop lever (fig. 9.11) the cam sleeve does not revolve.

The operation is as follows: Each selecting cycle is preceded by a *no-current* or start impulse. When a start impulse is received the armature is released and pulled away from the magnet pole pieces by the armature spring. The armature spring causes the head of the trip-off eccentric screw to depress the trip-latch plunger (fig. 9.11) thereby actuating the bell crank. The bell crank pivots downward on the right end of the trip latch raising its left end. The trip latch is moved out of engagement with the stop lever which releases

e stop arm allowing the selector-cam sleeve revolve with the main shaft. Each code bar positioned by a selector cam through the edium of a selector lever, sword, and -lever. (See fig. 9.12).

Holding Magnet Selector Unit

The holding magnet selector (figs. 9.13 and 9.14) is basically the same as the pulling magnet selector. The holding magnet selector,



1. Ribbon-spool shafts on bushings (remove spools) (2). 2. Ribbon-reverse shafts, upper and lower bearings. A
3. Ribbon shaft drive gears. B[2]
4. Clutch throw-out lever at ends of lever and at pivots B[2]
5. Main-bail roller. B[2]
6. Main-bail guide and groove on main bail. B[2]
7. Groove in main bail. A[1]

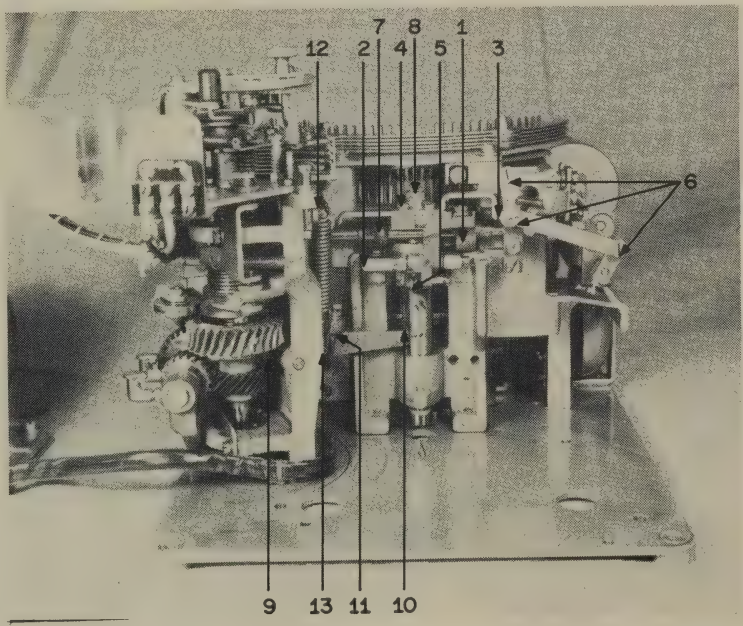
[1]Fill
[2]Sparingly
[3]2 or 3 drops

ig. 9.6—Lubrication points on left side of eletype Model 14 typing reperforator unit. oints marked *A* receive 1 or 2 drops of AE10 and those marked *B* receive Lubriate No. 630-AA.

. Ribbon-feed atchet and feed gear eeth. A[2]
. Ribbon-feed shaft etent plunger. A
. Ribbon-feed shaft 2 oil holes). A[2]
. Ribbon-feed lever il hole. A[2]
. Ribbon-feed lever oller. A
. Ribbon-reverse awls and links on earings (4). A[2]
. Ribbon-feed shaft etent. B[2]
. Main-bail plunger. A[1, 3]
9. Main-bail lever il cup just above erminal block. A[1]
0. End of lever in ain-bail plunger. A[2]
1. Main-bail adjustng screw. B[2]
2. Main-bail spring nchor. B[2]
3. Main-bail lever pring post. A[4]

[1]Fill cups.
[2]Sparingly.
[3]Saturate wick.
[4]Saturate washers.

Fig. 9.7—Lubrication points on back of Teletype Model 14 typing reperforator unit. Points marked *A* receive 1 or 2 drops of SAE10 and those marked *B* receive Lubriplate No. 630-AA.



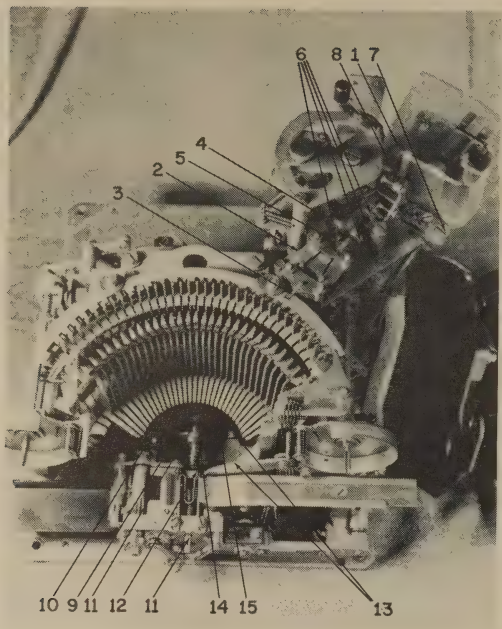


Fig. 9.8—Lubrication points of selector a platen mechanism. Points marked *A* rece 1 or 2 drops of SAE10 and those marked receive Lubriplate No. 630-AA.

1. Armature bearings (2). A[1]
2. Swords and selector levers between separating plates. A
3. Selector T-levers, small points of contact. A
4. Armature locking lever at pivot: A
5. Locking wedge at point of engagement with locking lever. A
6. Selector arm on pivot screws (2). sword contact points (2), and detent. A[1]
7. Selector-arm operating-screw head A[2]
8. Locking lever on separator surface. A
9. Shift rocker for
10. Shift rocker ar shift rocker lever pivot bearings (2). A
11. Platen-shaft bearings (2). A
12. Platen-block shaft bearing.
13. Shift lever. bearings (2). A
14. Shift lever whe It comes in contact with shift bell crank.
15. Shift bell-crank guide.

[1]On each point.
[2]Apply sparingly.

however, has its armature moved against the magnet by a cam, while the pulling magnet selector has its armature attracted to the selector magnet by magnetism.

The translation of electrical code impulses received from the signal line into mechanical motion is accomplished by the selector magnet, the armature, the selector arm, and the armature cam. (See fig. 9.14). The armature extension, which rides on the armature cam, moves the armature against the magnet at the time a signal-line impulse is received. If a current (marking) impulse is received, the armature will be held against the magnet; if a no-current (spacing) impulse is received, the armature will be released from the magnet. The selector arm is actuated by the armature extension because the selector arm spring makes a yield connection between these two parts. Therefore, instead of the armature extension, the selector arm is used to position the swords on holding magnet selectors.

The operation of the swords, T-levers, and code bars is the same as described in the "Pulling Magnet Selector Unit" section above. The holding magnet selector locking mechanism (fig. 9.15) operates in a manner similar to the locking mechanism of the pulling magnet selector described above. In the pulling magnet selector the armature extension mounts the locking wedge while in the holding magnet selector the selector arm mounts the locking wedge. Because the armature cam starts to move the armature toward the selector magnet before the locking lever releases the selector arm, the selector arm spring acts as a yie between the armature extension and the s lector arm.

Selector Unit Operation

It will be noted, from the two previous se tions, that the initial operations of the pulli magnet and holding magnet type of select magnets are different. As you follow throu the operation of each, they become more sir ilar in their operations, with their end oper tion essentially the same.

A detailed explanation of how a pulli type selector magnet operates in selecting t letter E (being received) together with a s quence chart for the selector mechanism w given in Chapter 8, fig. 8.28 under the di cussion of the Model 15 machine. Figure 9. gives an excellent close-up view of the top the Model 14 selector mechanism with t major parts identified.

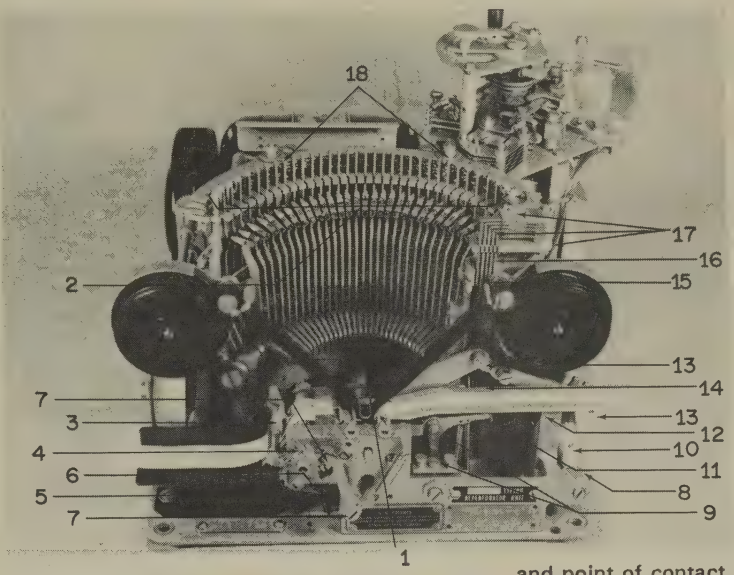
Range Finder

The range finder may be seen in the t view of the selector mechanism in fig. 9.1 It has a scale of 0 to 120, reading counterclo wise, as shown in the figure. A range find assembly consists of five principal parts as fo lows: (1) Scale, (2) Index arm, (3) Thum screw, (4) Stop lever, and (5) Trip latch.

For proper operation of the typing repe forator unit there must be a certain time i terval between the start of the rotation of t selector-cam sleeve and the time the select cams operate the selector levers. The purpo

the range finder is to adjust the parts of selector mechanism to operate in the proper time-interval sequence.

Adjusting the range finder to obtain the most favorable operation of the selecting mechanism may be referred to either as *orienting* or as *taking the range* of the typing reperforator. To set the range finder, move the index arm toward one end (either end) of the scale until that point is reached at



g. 9.9—Lubrication ints for Model 14 u n c h assembly. arked *A* receive 1 2 drops of SAE10 d those marked *B* ceive Lubriplate No. 630-AA.

Type bars at gment slot. A[1]
Pull bars. A[1]
Tape-tension lever earings (2). A[2]
Star wheel. A[2]
Feed-pawl earing. A
Punch bars at inch-bail guide mb. A
Feed-roll detent aring and roller. A
Punch-bail pilot-rew bearings (2). A[2]
Punch-bar bell-ank bearings and slot in punch rs. A
. Punch-arm sting bearings in l holes (2). A[2]
. Vertical-lever ll-crank bearings and at points of contact with punch-bar bell cranks. A[1]
12. Vertical-lever lower guide comb slots. A
13. Punch-bail adjusting-link bearings (2). A[2]
14. Vertical-lever pivot screw. A
15. Vertical-lever upper guide comb slots. A
16. Code-bar bell cranks at bearing and point of contact with vertical levers and code-bar locking lever (3). A
17. Code bars at posts. A

[1]On each point.
[2]Apply sparingly.

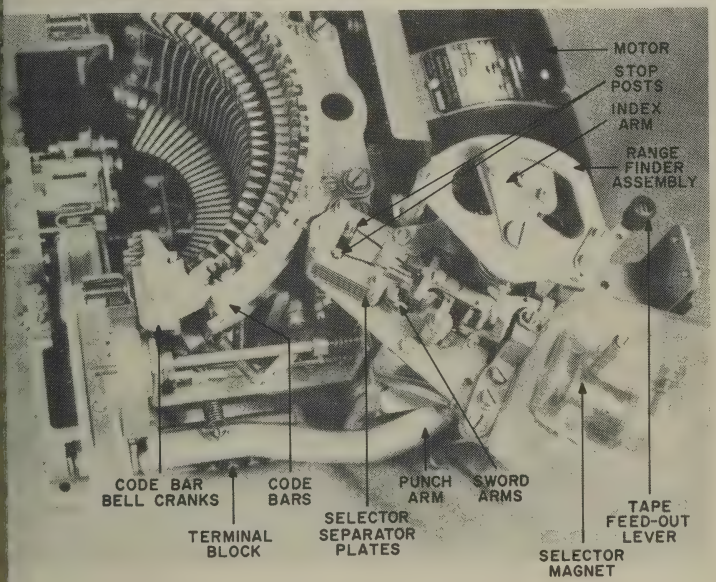


Fig. 9.10—Top view of Model 14 typing reperforator unit.

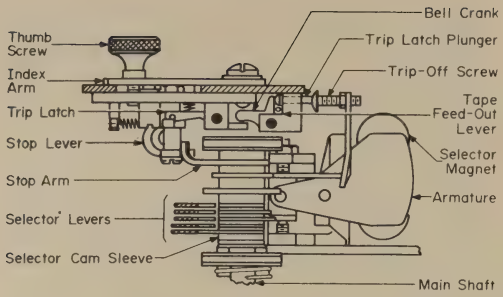


Fig. 9.11—Selector unit with pulling magnet.

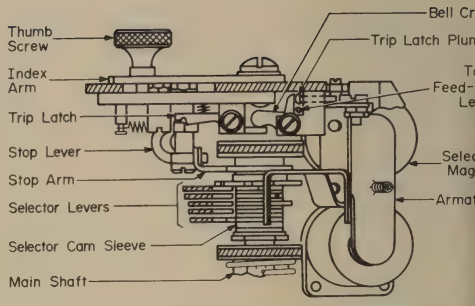


Fig. 9.13—Selector unit with holding magne

which the reperforator fails to print correctly. Then move the index arm back to the point where the reperforator prints correctly. Repeat this operation for the other end of the scale. This is the limit of the range in each direction. Midway between these points is the position most suitable for operating the selector mechanism in the proper time-interval sequence.

Moving of the index arm positions the stop lever (fig. 9.11) and selector cam sleeve to have the selector cam operate the selector lever when its related signal impulse is received by the selector magnet. Set to its correct position, the stop lever blocks the stop arm on the selector cam sleeve at the end of each five selecting impulses. The index arm is held, when set, by a thumbscrew.

The R - Y Test

The simplest possible method of setting the range finder has just been given. An inspection of the code forming elements (see fig. 1.2) of the letters R and Y indicates that by alternately sending these two letters that all elements of the code, and subsequently all of the code forming parts of a teletypewriter are put into play. One may be able to visually see the start of this series of actions by removing the receiving unit from a keyboard to

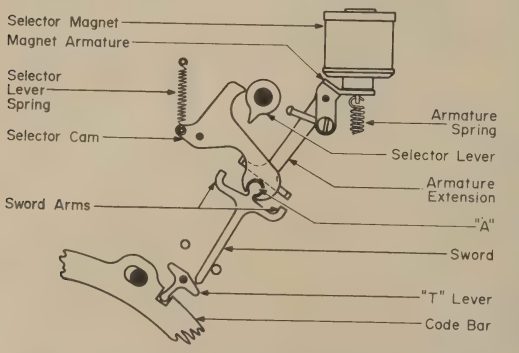


Fig. 9.12—Cross-section of the selecting parts of a pulling magnet.

make the keyboard transmitter mechanism vi ible for inspection. By alternately pressing th R and Y keys one can see that all of th locking levers are put into play by movin in and out. For this reason, it has been sta dard practice for many years to alternate send characters R and Y over and over agai as a test signal, when setting the range finde

Any bias or other distortion present in a R and Y test signal, or other test signal, ca have a bearing on when printing errors sta and stop as the index arm is moved up an down on the range scale. A typing repe forator, in good condition, should give a lowe scale reading between 10 and 15, and an up per scale reading between 85 and 90. Add th low and high readings and divide the resu by two to find the scale reading for best op eration. (For example, a low reading of 1 plus a high reading of 90 gives 105, which when divided by 2, gives a scale setting o 52.5, for best operation.)

Tape Perforating Mechanism

The major difference between the Model 1 typing reperforator and the Model 15 is tha one is a tape printer and perforator and th other is a page printer. A view of the punch block and typing reperforator of a Teletyp Model 14 machine is shown in fig. 9.17 an a detailed drawing of the tape perforatin mechanism is given in fig. 9.18. A sequenc chart for perforation is given in fig. 9.1 and the sequence chart for the printing mech anism is given in fig. 9.20.

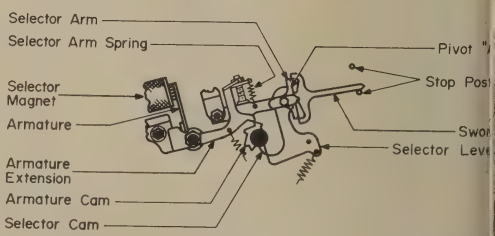


Fig. 9.14—Cross-section of the selecting parts of a holding magnet.

The tape-perforating mechanism consists of e punch arm casting, punch bail link, punch il, punch bell crank, punch selector fingers, d the punches. (See fig. 9.18.) Operation the punch-arm cam actuates the punches means of the parts listed above. The punch ector fingers are positioned by the punch ll-crank springs (fig. 9.18) so that the se-tion set-up in the code bars will be per-rated in the tape.

The positioning of the punch selector fin-rs takes place early in the upward stroke of e main bail. The motion of the code bar cking lever is utilized to operate the code ır bell cranks which move with the locking ver toward the code bars. If a code bar has en positioned to the right, the motion of the sociated code bar bell crank will be blocked the right end of the code bar as the lock-g lever moves toward the code bars. The unch selector finger will remain in position engage the punch as shown in fig. 9.18. the code bar has been positioned to the ft, the code bar bell crank will be free to llow the code bar locking lever. The parts nnecting the code bar bell crank and the unch bell crank turn in a clockwise direc-on, thus moving the punch selector finger to ıe left so that its recess will be under the unch. Shortly after the punch selector fingers ave been positioned, the punch arm cam oves the punch bail through the medium of ıe punch arm casting and the punch bail nk. When the punch bail moves to the ght, the punch engaging projections of the lector fingers which are in line with the unches, raise the punches causing them to

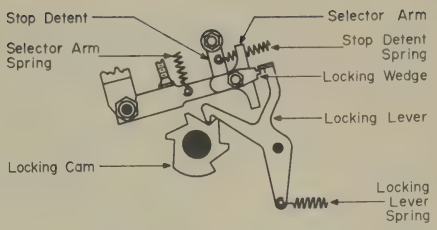


Fig. 9.15—Partial view of selecting mechanism showing only the locking lever operation.

perforate the tape. A projection on the punch bail engages the feed punch during every operation. The upstop screw in the punch bail limits overtravel of the punches to prevent mutilation of the tape.

Backspace Lever And Repeat Mechanism

Some of the Model 14 typing reperforator machines released to radio amateurs are supplied with a BACKSPACE lever as well as a REPEAT mechanism. Both features are highly desirable and add materially to the usefulness of such machines. The BACKSPACE lever is used for moving the tape backwards for the purpose of correcting errors. When the BACKSPACE lever is depressed, a pawl fastened to the lower arm of the backspace lever engages and turns the feed roll in a clockwise direction. This moves the tape backward one space for each operation of the backspace lever. The ribbon-guide lever lifts the ribbon guide and ribbon away from the tape, permitting the operator to see the printed characters on the tape. The backspace lever and associated mechanism are mounted on the punch block.

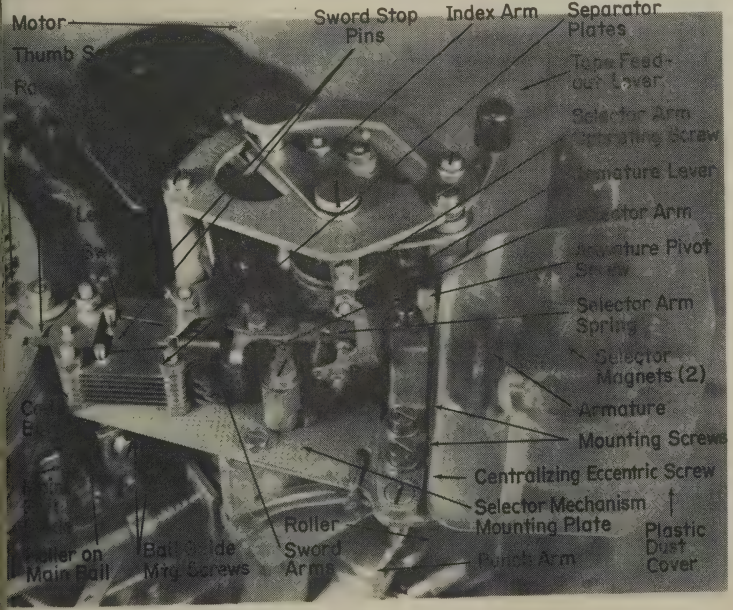


Fig. 9.16—Top view of the range-finder of a Model 14 typing reperforator and associated mechanism.

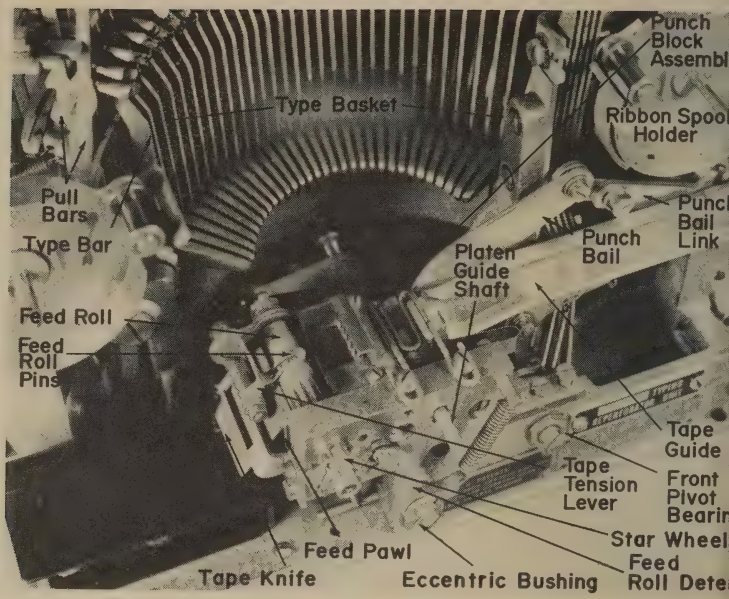


Fig. 9.17—View of punch block and typing reperforator of Teletype Model 14.

A desired code combination (character or function) may be repeatedly perforated so long as the REPEAT push button and any key lever are depressed simultaneously and kept depressed. Releasing the REPEAT push button stops the repeat operation.

Adjustments

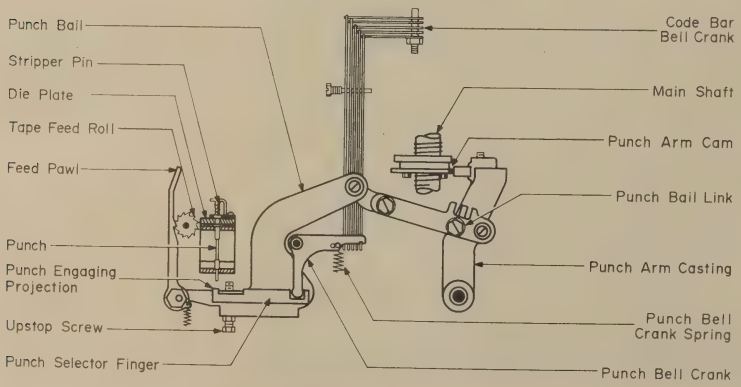
Detailed instructions for lubricating and adjusting the Model 14 are not given in this chapter as was given earlier for the Model 15 machine. Actually, there is not enough difference in the mechanisms, as a whole, to justify doing this and the requirements are basically the same. Refer to those sections covering the Model 15 that comes nearest to applying in each case. The detailed data given for lubricating and adjusting, the Model 15 will serve as an excellent guide for this and most any other machine as well.

Other Tape Machines

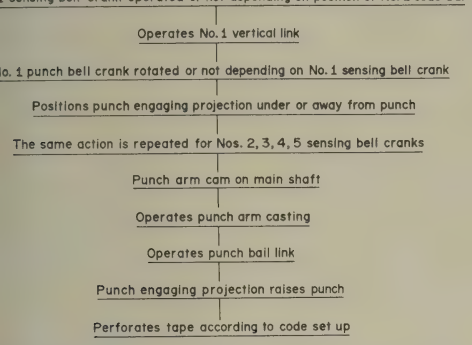
Besides the typing reperforating tape m chine there are two other general types. The is the *nontyping reperforator* type and t *typing non-reperforator* type. Neither of the two types has the flexibility or versatility the typing reperforator unit just describe Each was designed for a specific applicati for military or commercial use and each m have a limited application in amateur RTT operations as a supplementary piece of stati gear.

Nontyping Reperforator

A nontyping reperforator, such as the Tel type Model 14 (RPE26), is a motor drive machine that receives messages in the for of electrical impulses and records the messag in teletype code perforations in a paper tap



9.18—Tape - perfo- rating mechanism.


1 sensing bell crank operated or not depending on position of No. 1 code bar
Operates No. 1 vertical link
No. 1 punch bell crank rotated or not depending on No. 1 sensing bell crank
Positions punch engaging projection under or away from punch
The same action is repeated for Nos. 2, 3, 4, 5 sensing bell cranks
Punch arm cam on main shaft
Operates punch arm casting
Operates punch bail link
Punch engaging projection raises punch
Perforates tape according to code set up

ig. 9.19—Sequence chart for tape perfora-on mechanism of Model 14 typing reper-forator.

See fig. 9.21.) Unlike the machine just de-ribed, it is constructed as a single unit. It onsists of three basic parts: (1) Selector echanism, (2) Reperforating mechanism, (3) lectric drive motor. In addition there is the ape reel holder and in the case of the RPE26 here is also a polar relay, and, of course, here is the usual covering to keep out dust nd protect the mechanism. D.c. power for he operation of the selector magnet and polar elay, as well as the a.c. power, (for the elec-ic drive motor), must be supplied from an xternal source.

The tapes punched by one of these machines of the *chadless type,* similar to the tapes unched by the reperforator associated with he Teletype Model 19 machine. A chadless ape is one in which all of the chads are *ompletely severed* from the tape, leaving lean round holes.

Typing Nonreperforator

A typing nonreperforating machine such as he Western Union Telegraph Co. Simplex Printer 2-B is nice to have around as an xtra. It is a strip tape printer that was manu-actured by Teletype Corporation for the West-rn Union Telegraph Company. Quite a num-ber of these machines have been released to radio amateurs.

This rugged and dependable machine has one disadvantage. The machine does not use he standard 11/16 inch paper tape. It uses, nstead, a paper tape 5/16 inches wide which s not available on the surplus market or at places where the 11/16 inch tape is normally obtained. About the only place where the author has been able to obtain this tape in quantity is by purchase from the Western Union Telegraph Company and it usually comes with the underside gummed.

Teletype Corporation[19], manufactures a kit for use in converting the 2B printer so that it will use a 3/8 inch tape instead of the 5/16 inch tape. The 3/8 inch tape is a bit more standard but one might find that it too is difficult to find. Chances are that the original platen roll for the 5/16 inch tape will work for 3/8 inch tape. Otherwise part no. 6960 will be needed. Other parts that definitely will be needed are: (a) Tape guide (right)—part no. 6845; (b) Tape guide (left)—part no. 6930; (c) Tape guide tube for base—part no. 90139; (d) Feed roll—part no. 6932.

Figure 9.22 shows a general front view of the Western Union Telegraph Co. 2-B tape printer with all visible major parts or mechanisms identified. An inspection of this figure indicates that, for typing (sending) and printing (receiving), the 2-B is just about as simple as a teletypewriter can become. The on-off toggle switch shown on the left front is the power switch for the synchronous a.c. motor and was added by the author.

The synchronous a.c. motor was also added and required the acquisition of appropriate gears. The a.c. motor replaced a d.c. powered, governor-controlled motor. The radio reception interfering electrical noise generated by the motor brushes and governor contacts of such a motor can be reduced to a level acceptable for most receiving conditions except for perhaps DX. This is done by proper filtering, best done by the cut and try method.

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[19]5555 Touhy, Skokie, Ill. 60068.

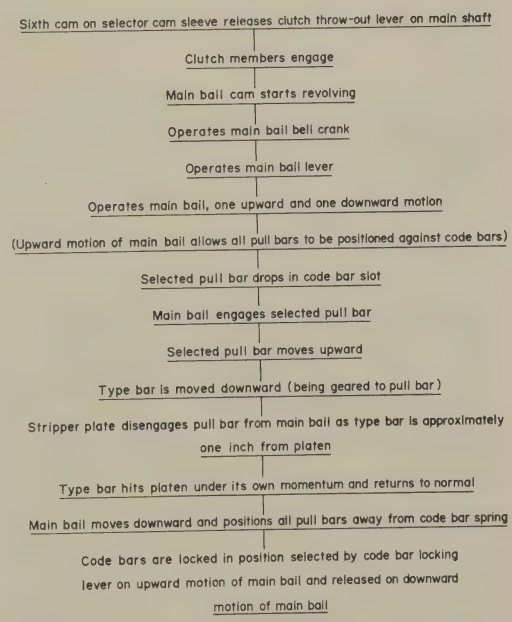

Sixth cam on selector cam sleeve releases clutch throw-out lever on main shaft
Clutch members engage
Main bail cam starts revolving
Operates main bail bell crank
Operates main bail lever
Operates main bail, one upward and one downward motion
(Upward motion of main bail allows all pull bars to be positioned against code bars)
Selected pull bar drops in code bar slot
Main bail engages selected pull bar
Selected pull bar moves upward
Type bar is moved downward (being geared to pull bar)
Stripper plate disengages pull bar from main bail as type bar is approximately one inch from platen
Type bar hits platen under its own momentum and returns to normal
Main bail moves downward and positions all pull bars away from code bar spring
Code bars are locked in position selected by code bar locking lever on upward motion of main bail and released on downward motion of main bail

Fig. 9.20—Sequence chart for printing mechanism of Model 14 Typing Reperforator.

End Of Line Indicator

All send-receive tape printer teletypewriters have one disadvantage in common. One can readily see the end of the line when monitoring sending with a page printer. One can not be so sure when monitoring sending with a tape printer. If everyone receiving was also using a tape printer there would be no problem, however, the CARRIAGE RETURN key as well as the LINE FEED key must be pressed for the benefit of those who are copying on a page printer. Obviously, the copy will "pile up" at the end of the line on the page printers until the sending operator thinks to send the CARRIAGE RETURN and LINE FEED signals. If not, the receiving operator hovers over his own machine and puts in the two necessary and missing functions at the proper times.

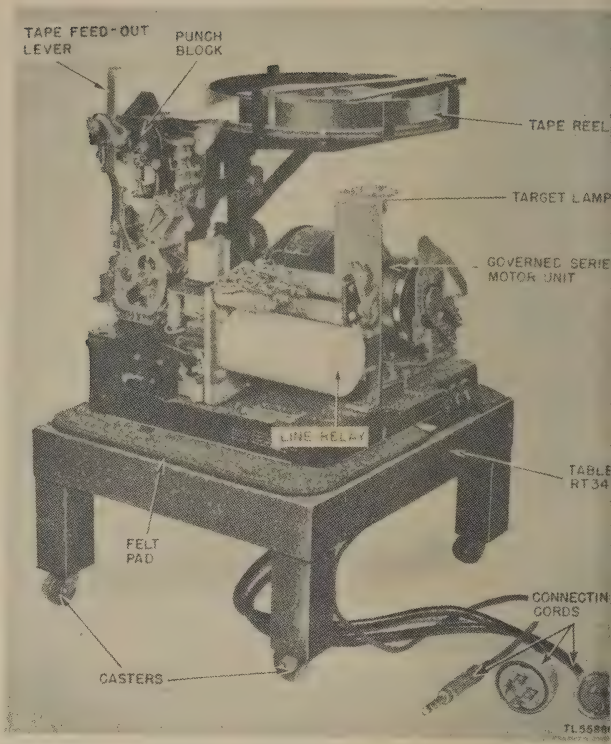


Fig. 9.21 — General view of Model 14 (RPE 26) non-typing reperforator.

It becomes apparent from the above that it would be most desirable to have some sort of end of line indicator for use with tape printers when sending. The 2-B tape printer shown in fig. 9.22 does have an "end of line indicator" and it may be seen at the right side of the machine. A close-up view of this mechanism is shown in fig. 9.23.

Basically, the "end of line indicator" shown here is a mechanical device that counts the letters, figures and spaces necessary to print one line of text on a page printer. When this is done a set of electrical contacts are closed which act as a switch to turn on a red signal light. This acts as a reminder or a signal that the sending operator should press both the CARRIAGE RETURN and LINE FEED keys. When this is done the mechanism resets itself and is ready to repeat the performance on the next line of text that is to be sent.

The principal part of the counter is a ratchet wheel (no. 3 in fig. 9.23 that advances one notch whenever any letter, figure, space or other function (except carriage return) key is pressed. The ratchet wheel has about sixty teeth that cover 85 percent of the outer circumference of the wheel. This leaves a smooth space on the circumference of the 1¼ inch diameter ratchet wheel of about 5/8 inch where there are no teeth. Each tim the no. 5 (counting from the rear) transmitte cam (hidden from view in fig. 9.23) mak one revolution a special cam follower (als not shown) rides *up* and *over* the no. 5 trans mitter cam moving the cam follower extensio (no. 1) up, moving the stepping pawl (no. 2 up causing the ratchet wheel (no. 3) to ad vance one notch or step. A second pawl (no. 4 acts as a stop to block or prevent the ratche wheel from slipping back. When approximate ly sixty characters have en sent a boss (nc 5) on the ratchet wheel esses against a fibe bumper (no. 6) closing set of electrical con tacts (no. 7). These co tacts act as an electri cal switch allowing cu ent to light the signa lamp (no. 8).

Sixty characters do not normally make full line so this gives the operator ample warn ing to finish a word or so, depending o their length, and come to a convenient plac to end the line. During this time, after the sixt characters have been sent, the ratchet whee can advance no further since the blank par of the wheel is in front of the stepping paw (no. 2). Any number of characters and/o functions (except carriage return) sent afte the first sixty characters do not affect the mechanism further. *Only* the CARRIAGE RE

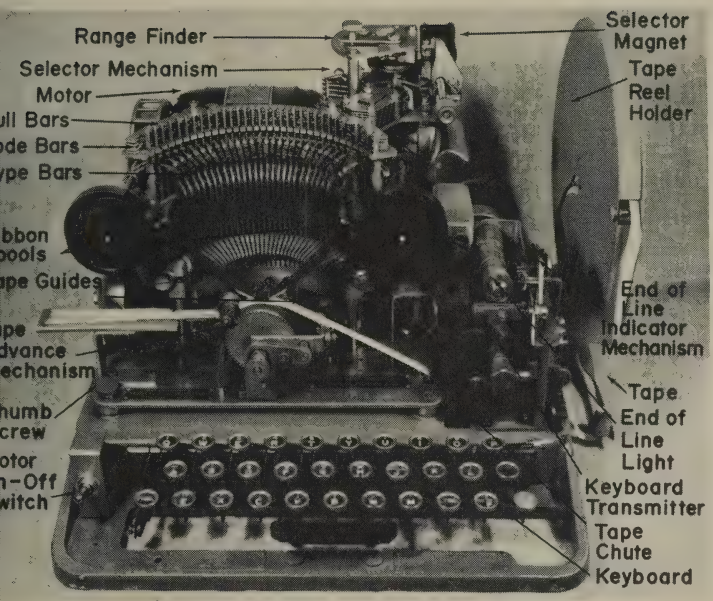


Fig. 9.22 — General view of a Western Union Telegraph Co. Simplex Printer 2-B that prints on a 5/16 inch paper tape but does not perforate the tape.

URN function releases the mechanism to re-at the above process all over again. Rota-on of the ratchet wheel, as outlined, winds p a "return spring" which returns the ratchet heel to its starting position as soon as the tchet wheel is released. The ratchet wheel is leased by a release lever (no. 10) which ises both pawls (no. 2 and no. 4) clear of e ratchet teeth allowing the spring driven tchet wheel to revolve counter-clockwise ack to the starting point. The release lever no. 10) is operated by a linkage (no. 9) onnecting it to the CARRIAGE RETURN key ver.

A line may be ended at any time that the perator desires to end it, long before the end f the line signal light turns on. He does this y simply pressing the CARRIAGE RETURN ey whenever he so desires. This also returns he counting mechanism to its starting position ach time that this is done regardless of the osition of the ratchet wheel.

Many of the Western Union 2B Simplex rinters are not equipped with an end of line ndicator mechanism as covered above. In such case, one must improvise or else accept the andicap of not having one. A "do it your-elf" system was given by W8BBB on pages and 4 of March 1966 RTTY.[20] This sys-em included an improvised electric switch nounted so that it was closed by the lock op cam every time that a character was ent. In addition, there were six resistors, two apacitors, a 400 p.i.v. diode, *etc.* forming a "counting" circuit. Unfortunately, it also counts non-spacing characters such as LTRS. FIG, and BLANK.

[20]Official monthly publication of RTTY Society of Southern California—W6AEE Editor.

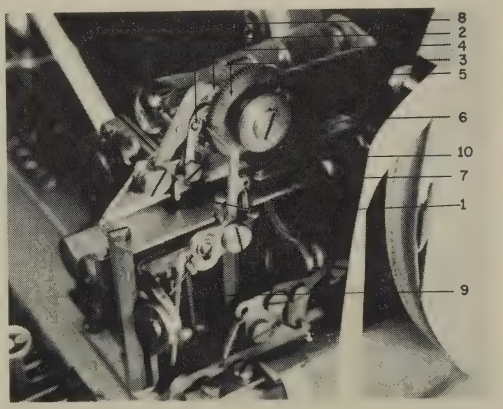


Fig. 9.23—Close-up view of the "end of line indicator" mechanism of the 2-B teletypewriter. Identity of the parts are as follows: 1. Cam follower extension; 2. Stepping pawl; 3. Ratchet; 4. Blocking pawl; 5. Switch boss; 6. Fiber bumper; 7. Contacts for signal lamp circuit; 8. Lamp; 9. Release linkage; 10. Release lever.

10

KLEINSCHMIDT MACHINES, TAPE READERS, TELETYPE MODELS 28 & 32

THE inventive genius of Mr. Kleinschmidt was covered in Chapter 1 in the introduction and history of the teletypewriter. Many Kleinschmidt machines of World War II vintage and later are finding their way into amateur circles. The Kleinschmidt Division of Smith-Corona Marchant, Inc., Deerfield, Illinois, is presently very active in the manufacturing of equipment for this service and the related field of data processing.

Although the present-day Kleinschmidt teleprinters do essentially the same things that other teletypewriters do, and in a very satisfactory manner, the means whereby they do this vary considerably from the descriptions of teleprinters covered up to this point in this text. This chapter covers some of the fundamental principles of the present Kleinschmidt Company machines. In addition, other present day machines are touched upon. The latter are only mentioned and not covered in depth since very few of these machines have found their way into amateur use.

Kleinschmidt Model 150

A Kleinschmidt Model 150 Teleprinte shown in fig. 10.1 would gladden the heart o any RTTY'er. More of these should find thei way into radio amateur teletype service in th future. It is the Kleinschmidt "old reliable comparable to the Teletype Model 15 althoug it is of later vintage. It is still a mainstay wit industry, so the radio amateur will just have t be patient. The general instructions for car servicing and lubricating given sometime bac for other machines should apply equally we in regard to the Model 150.

Early in this text it was pointed out that th sequential teleprinter system of transmissior was essentially a *mechanical position relatior ship to time* that is successfully transforme into an *electrical relationship to time.* In th receiving operation, the electrical relationshi to time is successfully (we hope) transforme into a mechanical position relationship to tim (same time—synchronous).

Figure 10.2 shows the keyboard and transmitter parts of the Model 150. This figure should be compared to figs. 8.2 and 8.3 as well as other figures showing the details of the keyboards of Teletype Corporation machines. One has no difficulty in seeing that there is quite a difference although all of the details, of necessity, of the Kleinschmidt keyboard and transmitter are not shown in this one view. Subsequent views of this mechanism as well as others of the Model 150 will bring out the detailed differences. In each instance try to correlate the mechanical parts and their mechanical operation to similar mechanical parts and operations covered earlier for Teletype Corporation machines.

Transmitting Mechanism

The code bars may be seen in place under and at right angle to all key levers in fig. 10.2. The detailed relationship between key levers and code bars are shown in figs. 10.3 to 10.5. An inspection of these figures and similar views of Teletype Corporation machines shows a striking similarity so the reader should experience no difficulty in following the action of key levers and code bars as pictorially illustrated in these figures.

From this point on the mechanisms differ somewhat, so the reader should study these figures (10.3 to 10.5) closely, referring back to similar views of Teletype Corporation equipment and their associated descriptions.

Fig. 10.1—General view of the Kleinschmidt Model 150 Teleprinter.

Character Repeat Feature

The Kleinschmidt Model 150 keyboard has a character repeat feature that is very handy. The keyboard is supplied with an extra key called the REPEAT key. By depressing this key along with the last key (character or space) that was depressed, the selected code group keeps repeating so long as these two keys are kept depressed simultaneously.

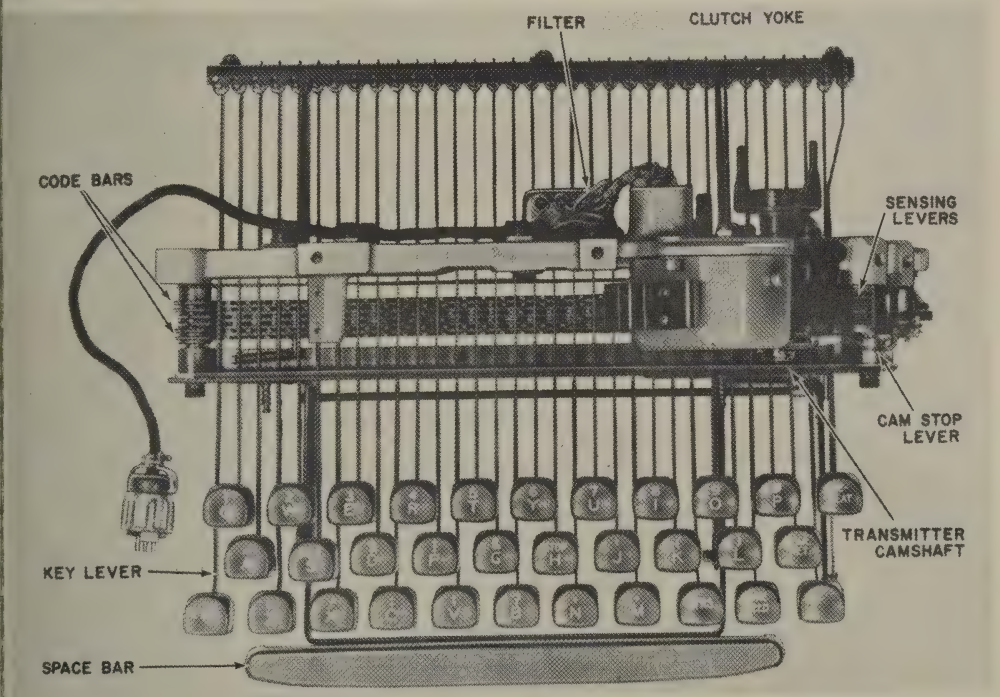


Fig. 10.2—Keyboard transmitter parts of the Kleinschmidt Model 150 Teleprinter.

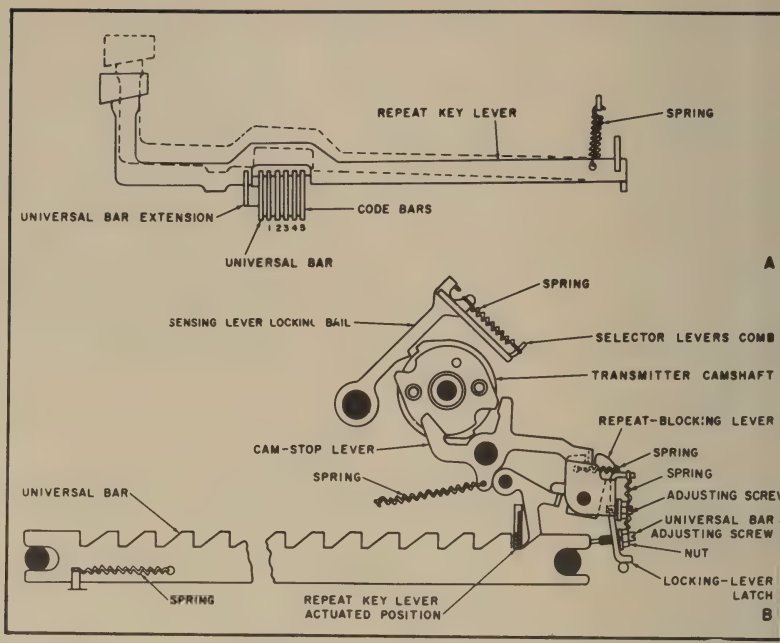


Fig. 10.3—Transmitter parts of the Kleinschmidt Model 150 Teleprinter.

Selector Magnet

The selector magnet has a U-shaped silicon steel core energized with a permanent bar magnet whose poles are labeled north and south as shown in fig. 10.6. The selector magnet has two separate line coil windings and two separate bias windings. The bias windings are only used under certain circumstances. When the bias windings are not used, the tw line coil windings are connected in parallel f 30 ma operation. Note the similarity betwe this selector magnet and the polar relay co ered earlier in Chapter 5. The mechanics the operation of this selector magnet and i associated mechanism are pictorially shown figs. 10.7 and 10.8.

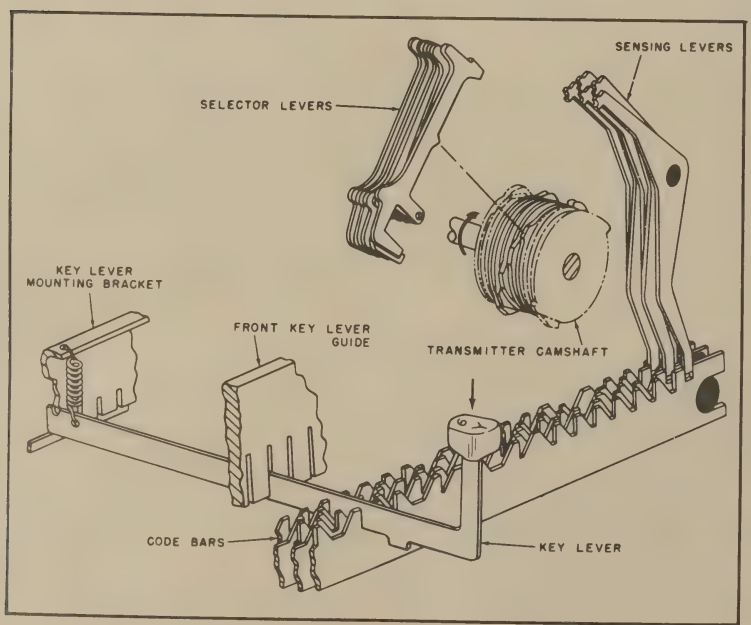


Fig. 10.4—Setting up mechanical form of Code by operating key lever of a Kleinschmidt Model 150 Teleprinter.

Printing Operation

It will be recalled that, with the Teletype re-iver mechanism, there were five code bars at had to be positioned properly for each aracter that was to be printed. With the leinschmidt Model 150 machine there are five *de rings* in the receiver mechanism that must positioned properly in accordance with the coming code group. In the former the code rs were positioned with pull bars. In the stance of the code rings in the Kleinschmidt achine they are controlled with a set of five verted T-levers (one for each) which are in rn controlled by five Y-levers. The interrela-onship of these parts is shown in fig. 10.9. n "exploded" view of the code ring cage is own in 10.10 and the basic components of e typing unit are shown in fig. 10.11.

Teletype Model FRXD9

Quite often an operator may type out and rforate a tape while receiving and be ready transmit it the instant the distant operator ands by. One practicing this procedure soon nds that there is a certain difficulty to over-me. Even when the Terminal Distributor TD) is placed as close as possible to the odel 14 Typing Reperforator, there is at ast twelve inches or more of tape between e sensing pins of the TD and the last aracter punched by the Model 14 Typing eperforator. One must sever the tape at this oint, or else send a long string of "blanks" order to allow all of the message portion of e tape to pass through the TD tape sensing, tape reading mechanism. Otherwise, the D "taut-tape" switch will stop the mechanism before the last portion of the tape message is sent.

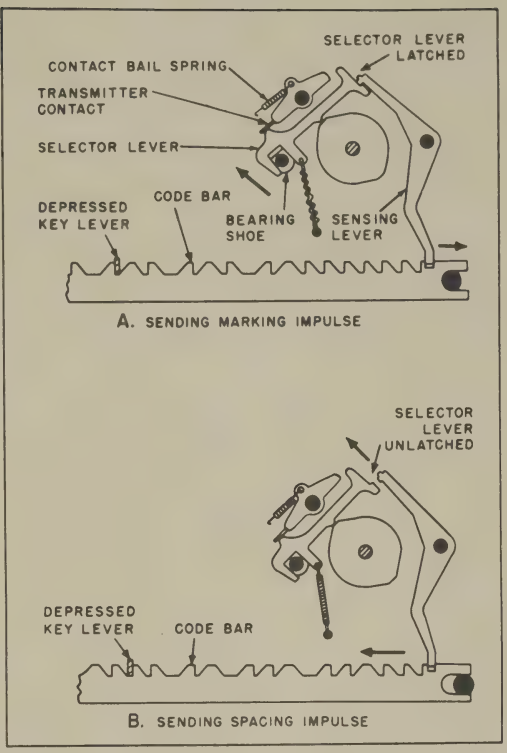


Fig. 10.5—An indication of how a marking impulse and a spacing impulse is sent with the transmitting mechanism of a Kleinschmidt Model 150 Teleprinter.

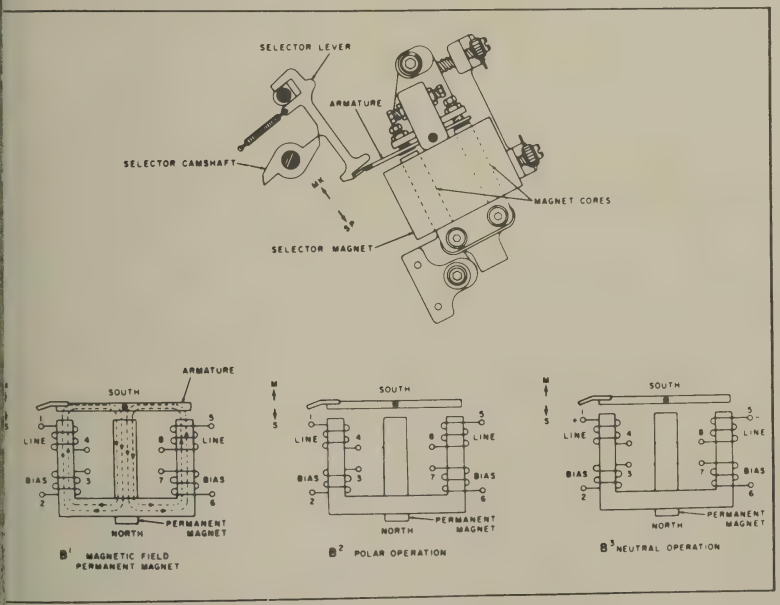


Fig. 10.6—Polar selector magnet of Kleinschmidt Model 150 Teleprinter.

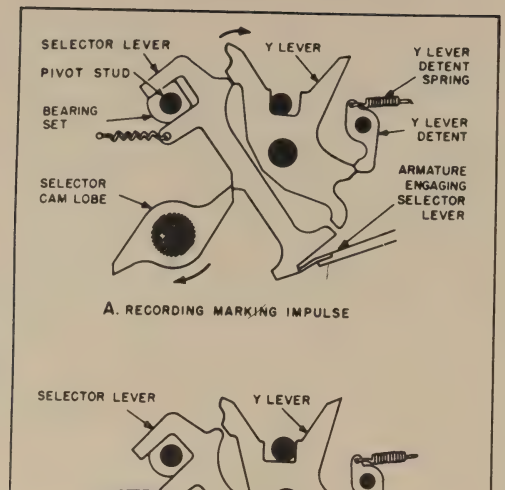


Fig. 10.7—Impulse recording portion of selector mechanism of the Kleinschmidt Model 150 Teleprinter.

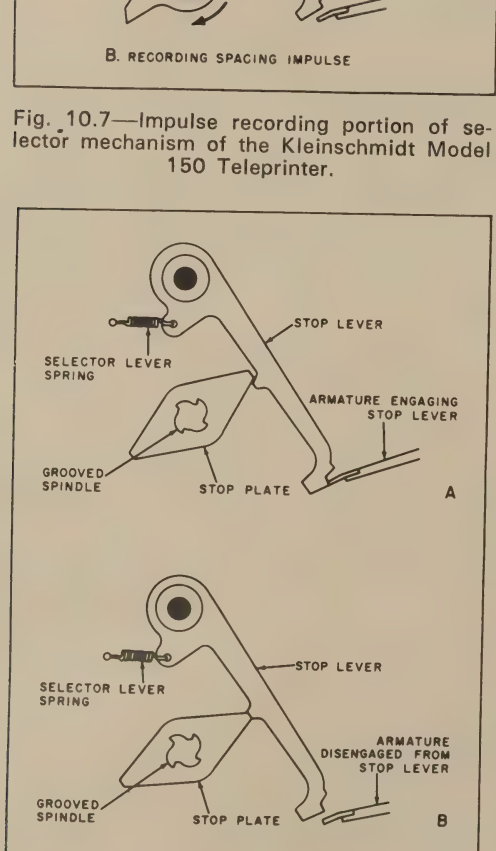


Fig. 10.8—Selector camshaft and stop plate of a Kleinschmidt Model 150 Teleprinter.

The situation may be further complicated the fact that the receiving operator may not quite finished with the typing of the "answe message when the sending operator sudden turns it "back to him". A minute or so lat the tape may suddenly grow taut and shut c his transmission when the TD catches up wi his slow typing of his answer.

Teletype Corporation developed the Mod FRXD which eliminates this objectionable fe ture encountered in the joint use of the Mod 14 Typing Reperforator and the separate Mod 14 Transmitter-Distributor (TD). The Mod FRXD combines the operations of these tw machines all in the one machine. The Mod FRXD is a one-motor device and will tran mit right on up to the *last character punche* Perforated tape can be stored in the form a loop, as with the two machine combinatio just mentioned, in case of a necessary dela in transmission. The machine is provided wi a pivoted tape transmitter, which is sometime called the "climbing monkey" by teletype r pairmen. It moves along the tape, whenever becomes taut, until it reaches a position or character away from the character positio or space in the punch block at that instant.

The Model FRXD has one disadvantage i that it does not have a keyboard nor is ther any provision for one. There are several ver sions of this machine, such as the FRXD3 FRXD4, FRXD5, FRXD9 and FRXD10. A of these are *typing reperforators,* except th FRXD3, which is a *non-typing reperforato* unit. The FRXD9 is shown in fig. 10.12 wit the cover and tape reel removed.

Model 14 Transmitter Distributors

The Model 14 TD, found singly or as a par of the Model 19 set, is probably used more tha any other tape reading and playback unit b the radio amateur RTTY'ers. First, it is a very sturdy and dependable unit and important, a well, is the fact that the Model 14 TD have been available to the radio amateur i greater quantities than any other unit, and at attractive prices that the amateur could af ford. Most of the other units are harder t obtain and some of them are not as adaptable to amateur use anyway.

There are several versions of the Model 14 Principal of these is the two channel unit and the Receiving Transmitter Distributors. The two channel unit transmits two sets of impulses with each pulse 11 milliseconds longs, or half that of the normal 22 millisecond pulse for the 5-level 60 w.p.m. code used for amateur work. This would require modifications for satisfactory amateur use. The Receiving Transmitter Distributors had a special application in military work involving classified messages. It,

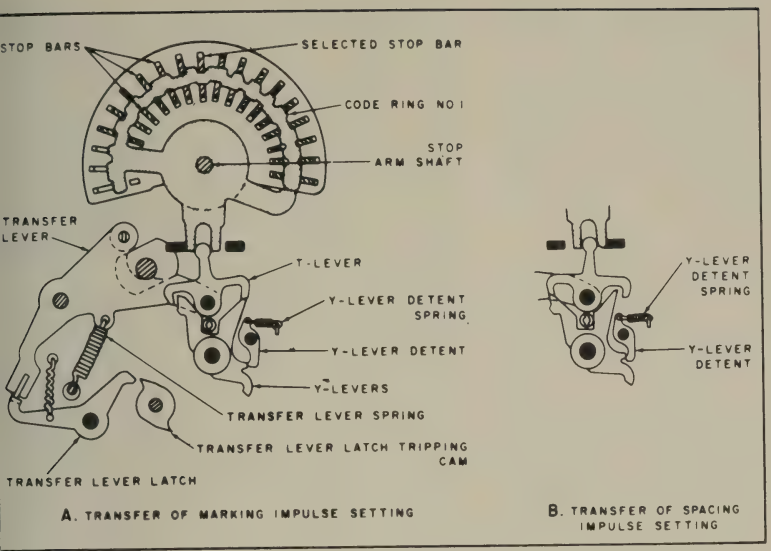


Fig. 10.9—Transfer mechanism operation of a Model 150 Kleinschmidt Teleprinter.

oo, would have to be adapted to amateur RTTY work.

A general view of the Teletype Model 14 TD was given in fig. 2.5 and 2.6. A general iew with many parts identified, is shown in ig. 10.13.

The TD unit *does not* punch or perforate tape. Its sole purpose is to transmit a tape, ither chad or chadless, that has already been unched. This is the reason that one may oc-asionally find an operator that may have such unit, even though he may not have tape unching equipment. Naturally, this operator would require access to tape punching equip-ment to prepare routine operating tapes, such as station equipment descriptions and the like.

Basically, a TD unit senses a perforated ape in such a manner that each hole, aside rom the row of sprocket drive holes, repre-ents a *closed circuit*. Likewise, each space, where a hole could have been punched but one was not punched, represents an *open circuit*. The sequential combination of each 5-group combination of these spaces determines which character or function is subsequently trans-mitted.

The five space groups, where holes may or may not have been punched, are in a row, and at right angles to the length of the tape. From this one might realize that the tape advances through the machine *one longitudinal space* at a time. This it certainly does, allowing for the sequential transmission of each group be-fore passing on to the next vertical line of code spaces. From a practical standpoint, the mo-mentary stopping of the tape for each vertical line of code spaces allows for the mechanical sensing of all spaces at the same time. For a brief moment a small sensing pin protrudes up through each hole (if present). There are five sensing pins so all spaces are sensed at the *same* time. The tape must be stopped long enough for all pins to protrude up through the holes in the tape and then to be withdrawn *after* the associated character has been trans-mitted. As one might further and rightfully surmise—the tape spends more time resting than it does in moving (or jumping). Perhaps the more correct description of the tape's movement through the TD is to consider it as a jumping and resting action. The jump action is so fast and the individual jumps so short that with a casual glance at the tape it appears to be standing still if you look at only the area being sensed; and to be moving continually if you look at the free end coming out of the machine.

Tape Sensing Mechanism

The tape sensing mechanism and the tape-feed mechanism in all units are closely asso-ciated. With the exception of the two-channel transmitter distributors, all units have similar tape sensing mechanisms. Each tape sensing mechanism (except those in the two-channel units) has a group of five similarly shaped contact levers with associated contact tongues, a contact block with five pairs of contact screws (five marking and five spacing), and a group of parts consisting of the contact-lever bail, operating lever, roller, and operating cam. Two-channel transmitter distributors have two such mechanisms.

Figure 10.14 shows the contact lever which has three irregularly shaped extensions, A, B, and C, and is pivoted as indicated by the desig-nation S. Extension C is turned up at one end, and a small tape pin, projecting vertically

upward, is set into the end of the extension. Extension B extends vertically downward and engages the contact lever bail. The contact tongue assembly is attached to extension A by a pivot located at the rear edge of the contact tongue. The five contact levers are mounted on the same shaft, S, and are spaced so that the distance between the tape pins is the same as the distance between the perforations in the tape.

In non-transmitting position, the operating lever roller is on the peak of the operating cam and, in this position, through the medium of the operating lever and the contact-lever bail, holds the contact levers in such a way that the tape pins are below the upper surface of the tape guide, and the contact tongues rest against the spacing (upper) contact screws. The contact tongue assemblies are pivoted at their edges on the contact levers. The front edges of the contact tongue assemblies are held against the contact levers by tension in the contact-lever springs.

As a single character (or function) is transmitted by the transmitter distributor, the cy or operation of the tape sensing mechani starts when the stop arm (see fig. 10.13) moved out of engagement with the lug on t stop cam (either by hand or electrically). T allows the main shaft (including the operati cam and the distributor brush assembly) (fi 10.13 and 10.15) to start turning. Imme ately after the main shaft begins to turn, t operating lever roller rides off the peak of t operating cam (fig. 10.15) and releases pr sure on the contact lever bail (figs. 10.13 a 10.15). When pressure on the bail is release the contact lever springs rotate the conta levers on shaft S (fig. 10.14), so that the ta pins move upward through the openings in t transmitter top plate. If there is a perforat tape in the transmitter as the tape pins mo upward, those pins which have holes abo them in the tape pass through the holes a continue to move upward until the associat contact tongues rest against their markin (lower) contact screws.

If there is no hole in the tape direct

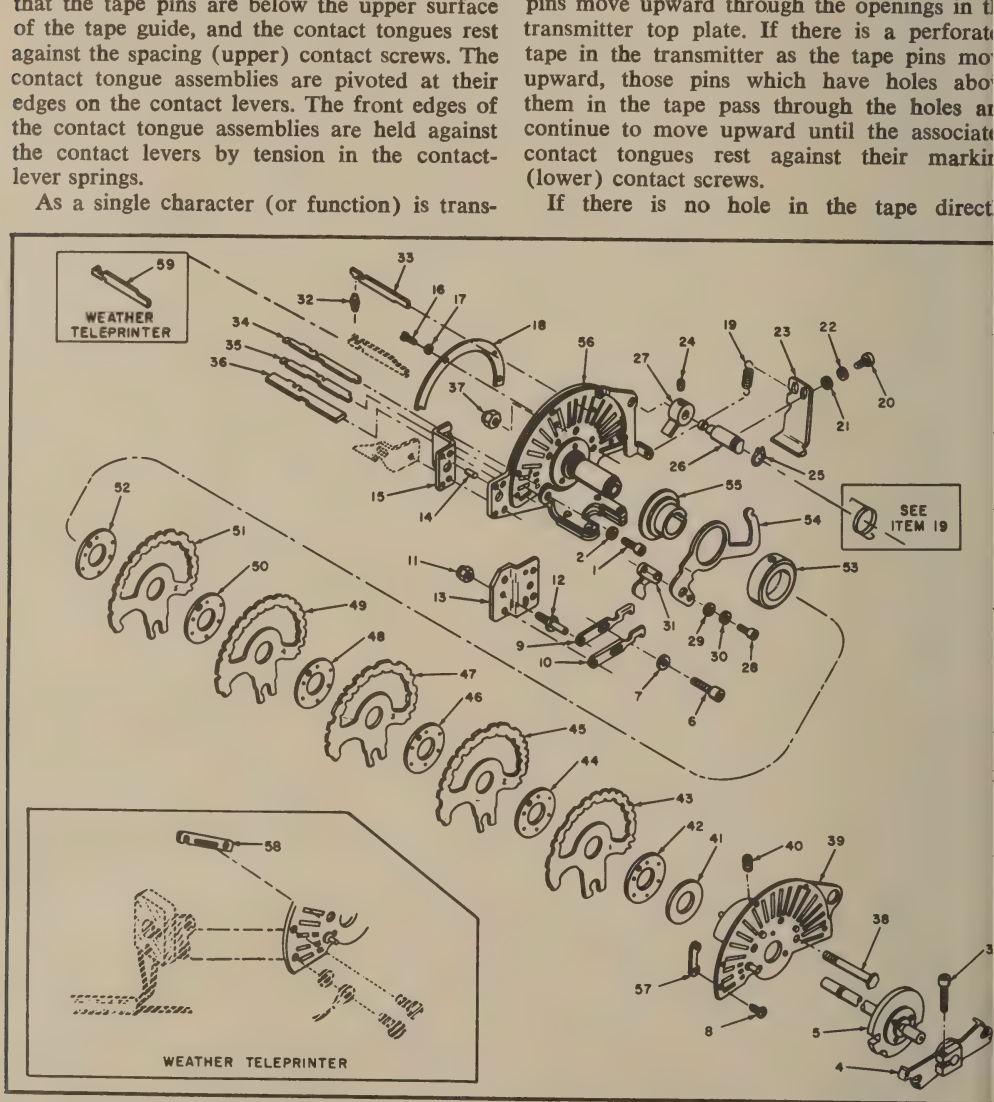


Fig. 10.10—An exploded view of the code ring cage of a Kleinschmidt Model 150 Teleprinter.

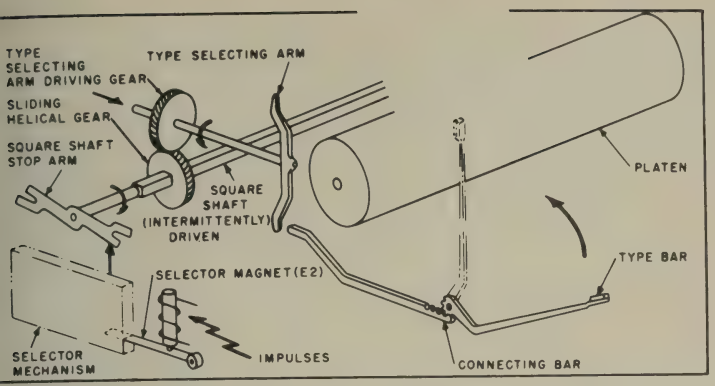


Fig. 10.11 — Basic components of typing unit of a Kleinschmidt Model 150 Teleprinter.

bove a contact pin, the upward movement f the pin is blocked by the tape, and the ssociated contact remains against its spacing upper) contact screw. The moving of the ape pins and the positioning of the contact ongues take place during the transmission of e start impulse, and they retain their positions uring the transmission of impulses No. 1, 2, 3, and 5. At the beginning of the stop impulse, e operating lever roller begins to ride up to e peak of its cam and causes pressure on the ontact lever bail. This pressure causes the ontact levers to rotate on shaft S until the pe pins are pulled below the surface of the pe guide, and the contact tongues are moved gainst the spacing (upper) contact screws.

The transmitting cycle ends when the operating lever roller reaches the peak of its cam. Because of the small amount of separation between the contact tongues and the contact crews, the transition from the marking to the pacing contacts takes place before the contact pins recede below the surface of the tape guide. The contact tongues stop moving upon striking the spacing (upper) contact screws, but the contact levers continue to move until the operating lever roller rests on the peak of its cam. The difference in movements is absorbed by the contact lever springs. A view of the

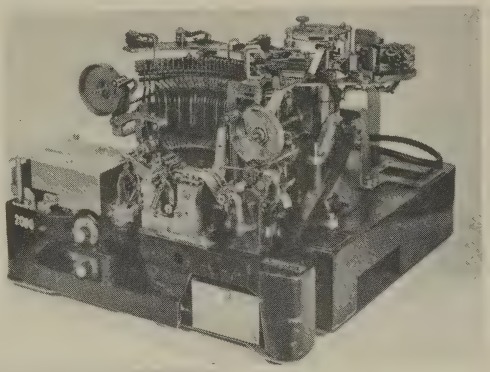


Fig. 10.12 — An inside view of the Teletype Model FRXD9 with the cover and tape reel removed.

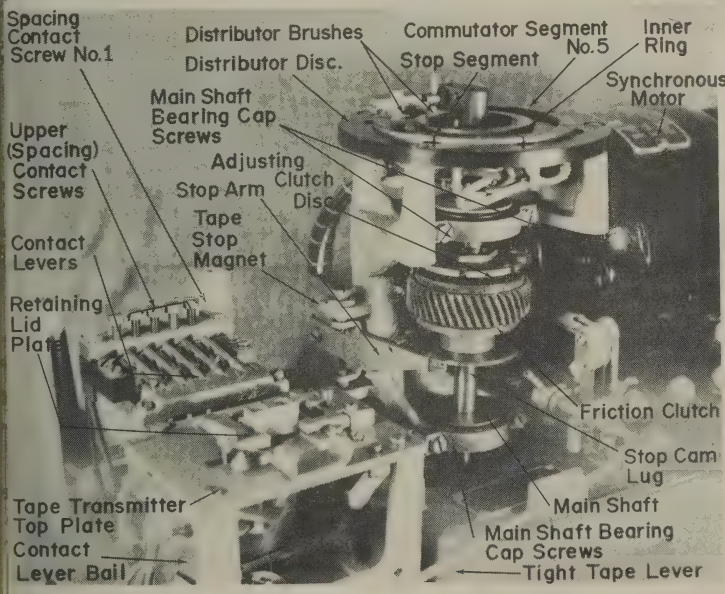


Fig. 10.13 — General view of Teletype Model 14 Transmitter Distributor with the large cover removed from the distributor mechanism and motor. The skirt and back-top plate of the tape transmitter sensing unit is also removed. Various parts are pointed out and identified.

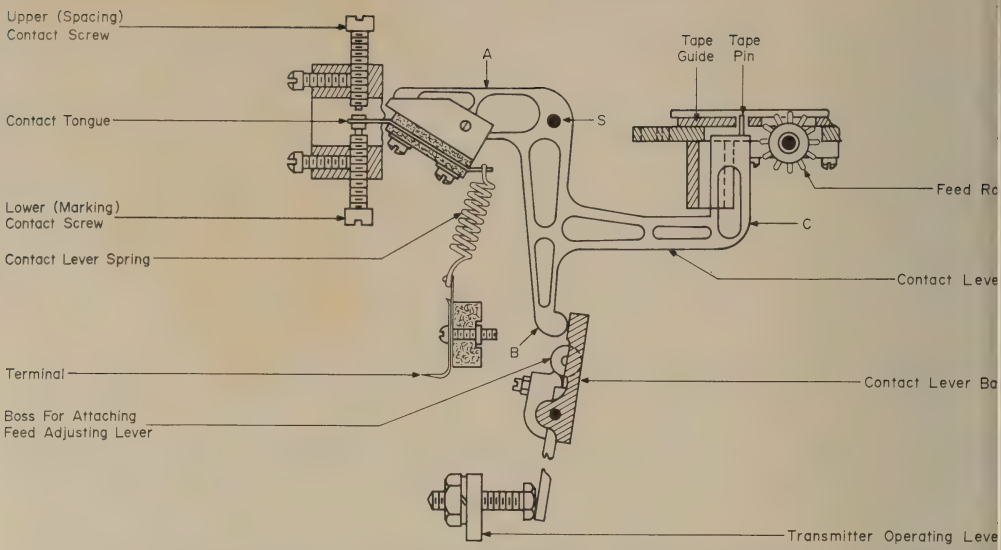


Fig. 10.14—Cross-section of tape sensing mechanism of Teletype Model 14 Transmitter Distributor.

tape sensing mechanism is shown in fig. 10.16.

Tape Feed Mechanism

A cross-section of the tape feed mechanism is shown in fig. 10.17 and details of this mechanism may also be seen in fig. 10.16. The principle of operation of the tape-feed mechanism is the same for all Model 14 Transmitter Distributors except for an army version (TG-21/FG) in which a tape-feed suppression mechanism is incorporated. The description that follows is for the standard type and the one most likely to be available for amateur use.

Pivoted on shaft S with the five contact levers is a sixth lever known as the *feed lever*. The feed lever moves in unison with the contact levers since extension B of the feed lever extends vertically downward and engages the contact lever bail in the same manner as the five contact levers. When the operating lever roller rides off the peak of its cam, the feed lever rotates on shaft S under tension of its spring in the same manner as the contact levers. The upward movement of extension C of the feed lever enables the feed pawl to engage a tooth in the feedroll ratchet. The downward movement of extension C, as the operating lever roller rides up to the peak of its cam, causes the feed pawl to exert pressure on a ratchet tooth and thereby turns the feed roll a distance corresponding to that between two teeth on the feed-roll ratchet. A detent roller, which bears upon the ratchet teeth, is provided to insure even movement of the feed roll. The tape-feed mechanism is designed so that the feed pawl does not engage a ratchet tooth until the tape pins have been pulled below the surface of the tape guide. This action prevents tearing of the tape by making certain that it does not move before the pins are withdrawn.

Distributor Disks

Various views of the distributor disks may be seen in figs. 10.13, 10.18 and 10.19. The

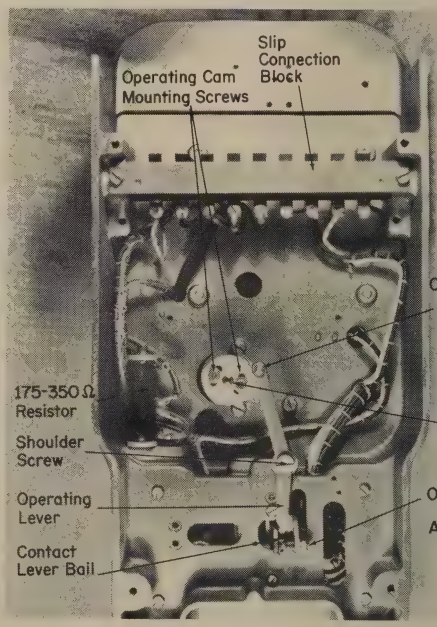


Fig. 10.15—Bottom view of Transmitter Distributor with major parts identified. The base plate has been removed.

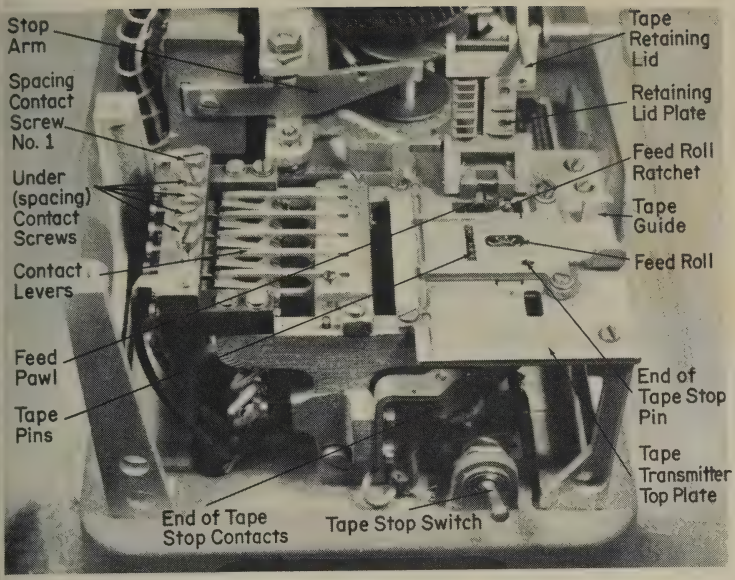


Fig. 10.16—Close-up view of the front end of a TD showing some parts not clearly visible in the preceding figures.

distributor consists of the distributor disk and the distributor brush assembly (fig. 10.13). The distributor disk consists of two concentric conducting rings mounted on a disk of insulating material. The outer ring is divided into seven segments; the inner ring is a continuous conductor. Segments of the outer ring correspond to the impulses of the teletypewriter code; that is, a start segment, five code segments, and a stop segment. The start segment precedes the No. 1 segment, and the stop segment follows the No. 5 segment (fig. 10.19).

The distributor brush assembly consists of a pair of brushes clamped in a metal brush holder. The brush holder is attached to the brush holder arm, which is mounted on the upper end of the main shaft. The brushes are spaced in the brush holder the same distance apart as the concentric rings on the distributor disk, and they revolve with the main shaft.

The distributor brush assembly makes one complete revolution to transmit the code combination for each character or function. When the distributor brush passes over the start segment, a spacing impulse always is transmitted; when the brush passes over the stop segment, a marking impulse always is transmitted. These two impulses keep the transmitter distributor and the receiving teletypewriter equipment in step or in synchronism by control of the starting and stopping of the receiving teletypewriter mechanisms. The receiving mechanisms start to revolve when they receive the start impulse from the Transmitter Distributor. If all teletypewriter mo-

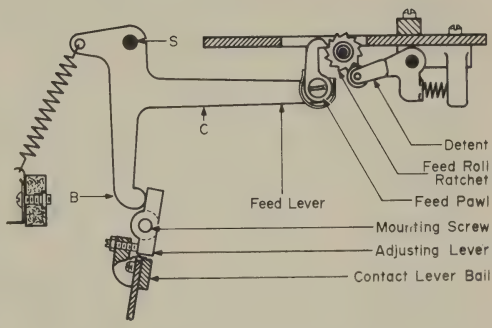


Fig. 10.17—Model 14 TD tape-feed mechanism, cross section.

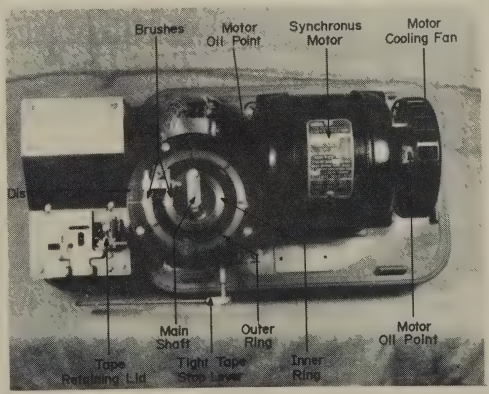


Fig. 10.18—Top view of the Model 14 TD.

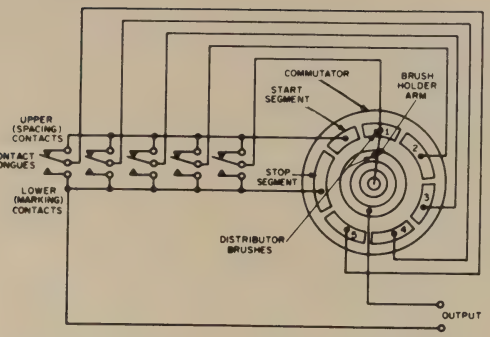


Fig. 10.19—Model 14 Transmitter Distributor signal circuit which is operated by the tape sensing mechanism.

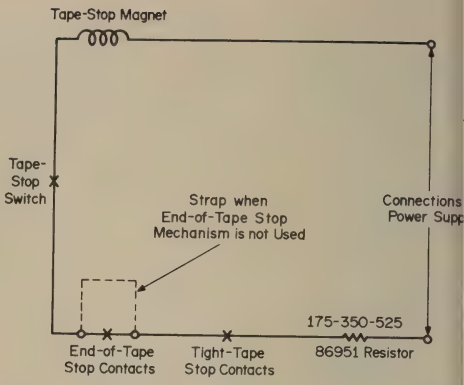
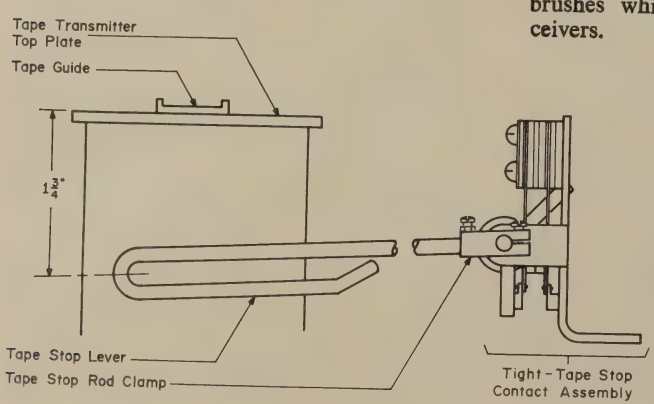


Fig. 10.20—Transmission control circuit f Transmitter Distributor TT-52/FG and XD8 type transmitter distributor, schematic di gram (Model 14's).

tors in the circuit are operating at the proper speed, the receiving mechanisms select the No. 1 impulse while the distributor brush is passing over the No. 1 segment. The Nos. 2, 3, 4, and 5 impulses are selected as the distributor brush passes over the Nos. 2, 3, 4, and 5 segments in a like manner. The receiving mechanism stops after receiving the stop impulse from the transmitter distributor. Because the receiving mechanisms revolve slightly faster than the distributor brush assembly, the receiving mechanisms come to a complete stop before the brush assembly completes the revolution and sends the next start impulse. Therefore, slight differences in speed are not cumulative because the distributor brush assembly and receiving teletypewriter mechanisms start together at the beginning of the transmission of each character or function.

A diagram of the signal circuit of Transmitter Distributor TT-52/FG and the XD 82 type Transmitter Distributor is shown in fig. 10.19. The signal line connects to the inner (continuous) ring on the distributor disk; the seven segments of the outer ring connect to the five contact tongues and the marking battery (start segment is not connected in neutra operation but is connected to spacing battery i polar operation). The distributor brush assem bly closes the circuit between the rings on th distributor disk. One terminal of the line ba tery usually is grounded. The signal line and th line battery are connected to the transmitte distributor through the slip connection bloc or terminal board. The output from the TI may be inserted in any circuit such as tha shown in fig. 3.1 or fig. 3.5. A tape fe through the TD would operate the selecto magnet (fig. 3.1) of a teleprinter such as th Model 15 page printer or tape printer such as Model 14. The TD *must never* be placed i series with a printer selector magnet and batter without a current limiting series resistor suc as shown in figs. 3.1 and 3.5. Coils and capa citors are used as filters and replaced in th leads between the terminals of a slip connectio block (or terminal board) and the inner rin of a distributor disk and the contact screws These filters suppress sparking of the distributo brushes which can cause noise in radio re ceivers.



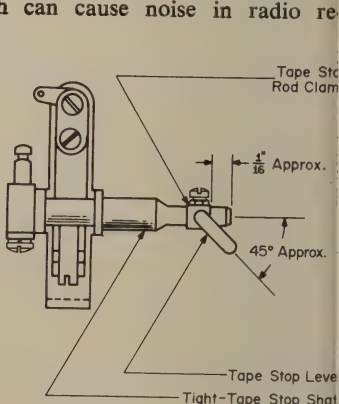
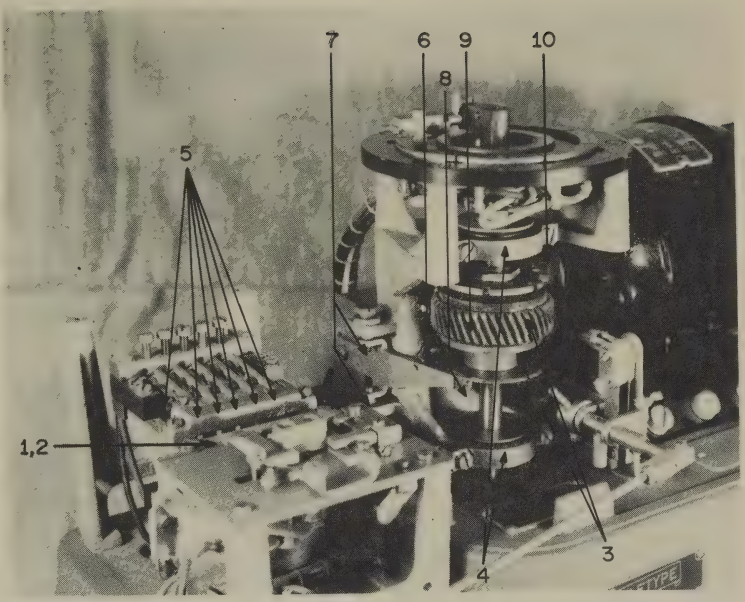


Fig. 10.21—Loop-style tight-tape stop mechanism for Model 14 TD unit.

. Contact Springs. A[1,2]
2. Feed-lever spring. A[3]
3. Friction clutch feltwashers. A, C[4]
4. Main-shaft bearings. A[5]
5. Bearings of contact levers and feed lever. A[5]
6. Stop lever spring. A[2, 5]
7. Stop lever bearings. A[5]
8. Stop cam lug (latching & camming surfaces). A, C[5, 8]
9. Main-shaft gear and motor pinion. B[2]
0. Motor bearing oilers (two). B[7]

Do not lube ends of contact lever spring.
Apply very thin film to prevent rust.
One drop to each end.



[4] Saturate with oil; coat with grease.
[5] One or two drops of oil.
[6] Coat with grease.
[7] One or two strokes of the grease gun.
[8] Thin grease film.

Fig. 10.22—Model 14 TD lubrication points. Points marked A receive 1 or 2 drops of SAE10, points marked B receive Lubriplate No. 630-AA and points marked C receive graphite grease.

Transmission Control

A transmitter distributor motor furnishes power to the main shaft by use of the motor pinion, main-shaft gear, and a *friction clutch* (except in the two-channel type, which has no friction clutch). When the motor is running, transmission is stopped by blocking the rotation of the main shaft and is started by unblocking it. The blocking is done by the stop arm which is under control of the *tape-stop magnet* and the *stop-arm spring*. The tape-stop magnet, when energized, holds the stop arm out of engagement with the stop cam lug, which permits the main shaft to revolve. When the magnet is de-energized, the spring pulls the stop arm against the stop cam in the path of the stop cam lug of the stop cam. The main shaft stops revolving when the stop cam lug engages the stop arm. Operation of the tape-stop magnet is controlled by closing or opening the series circuit which includes the tight-tape stop mechanism, tape-stop switch, the end-of-tape stop mechanism (when used), and the No. 86951 resistor. Each is described in the following paragraphs. The transmission control circuit for Transmitter Distributor TT-52/FG and XD82 type transmitter distributor is shown in fig. 10.20. It will be noted in fig. 10.20 that the TD operation may be stopped by *any one* of *four* different ways. The tape-stop magnet operation is a normal function in the operation of the machine and has already been covered. The other three methods of controlling the operation of the tape are given below.

Tape-Stop Switch

The tape-stop switch is provided so that transmission can be stopped by hand. The opening of this switch de-energizes the tape-stop magnet, which allows the stop arm to engage the stop cam lug and stop transmission. It is wired in series with the tape-stop magnet, the tight-tape stop contacts, and the end-of-tape stop contacts. Designation plates on the transmitter distributor snap panel show switch positions as ON and OFF or SEND and STOP.

Tight-Tape Stop Switch

The tight-tape stop mechanism (sometimes called the auto-stop mechanism) is designed to stop transmission automatically if the tape which is feeding into the transmitter becomes tangled or if all the slack is taken up in the tape; thus mutilation of the tape-feed holes is prevented. The normal operating position of the tight-tape stop lever is approximately parallel to the base of the transmitter distributor. The contact operating post bears against the tight-tape stop (fig. 10.21) contact insulator and holds the contact closed. When the slack

in the tape is taken up, or a tangle in the tape reaches the tight-tape stop lever, the lever is raised which permits the tight-tape stop contacts to open and the transmission is stopped. In some teletypewriter installations, tape-guide wires are mounted on the transmitter distributors to guide slack tape close to the tight-tape stop lever. The tape-guide wires are desirable, but are not necessary for satisfactory operation.

End-Of-Tape Stop Mechanism

The end-of-tape stop mechanism is used on transmitter distributors in some teletypewriter installations to stop transmission automatically when a length of tape has passed through the transmitter. The mechanism consists of a pair of contacts and an end-of-tape stop pin. The pair of contacts is mounted beneath the the tape transmitter top plate and wired in series with the tape-stop switch and the tight-tape stop contacts. The end-of-tape stop pin extends from the contacts upward through a hole in the transmitter top plate into a hole in the tape-retaining lid. As long as there is tape in the transmitter and the tape-retaining lid is closed, the end-of-tape stop pin is forced down and holds the end-of-tape stop contacts closed. As soon as the end of the tape passes the end-of-tape stop pin, the pin moves upward into the recess in the tape-retaining lid. The movement of the pin allows the contacts to open; thus the control circuit opens and transmission stops. The end-of-tape stop mechanism is not furnished with the XD82 type transmitter distributor.

Motors

Like so many of the teletypewriter machines, many of the TD's were supplied with governor controlled motors designed to operate from either d.c., 25 cycle a.c. or 60 cycle a.c. This was particularly true for the earlier models. The machine that the radio amateur gets today may still be supplied with a governor controlled motor. It is recommended that this is replaced with a synchronous a.c. motor since they are not hard to find and are very reasonably priced. Be sure that the replacement has the same physical size and will fit into place without any modifications.

Main-Shaft Friction Clutch

All model 14 Transmitter Distributors (except those of the two-channel type) have main-shaft friction clutches (fig. 10.13). The main shaft friction clutch transmits power to the tape transmitter and distributor; it consists of the main shaft gear and two felt washers (one on each side of the gear) mounted on the main shaft between the hub of the main shaft and a friction disk. A friction spring exerts pressure on the friction disk, which presses the felt washers tightly against the revolving mainshaft gear. The friction between the parts exerts a torque on the stationary main shaft, which causes it to turn when the stop arm is moved out of engagement with the stop cam lug. The amount of torque transmitted by the friction clutch depends on the pressure exerted by the friction spring. The pressure is increased or decreased by loosening a locknut and tightening or loosening an adjustable clutch disk, or by the amount of lubrication on the felt friction clutch washers.

Since no friction clutch is provided in the two-channel type transmitter distributor, the distributor brushes rotate continuously with the motor. On all other models, because of the presence of the main shaft friction clutch, the main shaft may stop rotating even though the main shaft gear, which is not attached permanently to the shaft, continues to be rotated by the motor pinion with which it is meshed. When the main shaft stops rotating, the distributor brush assembly also stops; thus transmission is stopped.

Preventive Maintenance

Differentiation between preventive maintenance and trouble shooting and repair as well as the importance of preventive maintenance was covered earlier in connection with the teletypewriter. It is just as important in connection with the TD so an added mention here is in order.

The following techniques are suggested for general preventive maintenance. Use No. 0000 sandpaper to remove corrosion. Use a clean dry, lint-free cloth or a dry brush for cleaning (1) If necessary, except for electrical contacts moisten or brush with a dry cleaning solvent (SD), such as Energine; then wipe the parts with a dry cloth. (2) Clean electrical contacts with a cloth moistened with carbon tetrachloride; then wipe them dry with a cloth, and burnish them. If available, dry compressed air may be used at a line pressure not exceeding 60 p.s.i. to remove dust from inaccessible places; be careful, however, or mechanical damage from the air blast may result. The TD unit in average radio amateur service does not need as much maintenance as would be required in daily commercial service.

Lubrication

The lubricants needed for the TD are the same (SAE 10 oil and Lubriplate No. 630AA grease) as those listed for the teletypewriter with the addition of a soft graphite grease

rt of powdered graphite (obtainable from ove mentioned source) with four parts Lu-iplate No. 630AA grease to form a suitable aphite grease (GG). The same general in-uctions given for cleaning and lubricating teletypewriter, are also correct for the TD. e principal lubrication points are pointed t and the amounts identified in fig. 10.22.

Cleaning

Use solvent (SD) to remove oil, grease, gum-y deposits, and small amounts of soluble aterials such as dirt, dust, mud, paper lint, . Do not use the solvent on rubber products for cleaning items for which carbon tetra-loride is specified. After using the solvent, pe the equipment dry so that a white film residue is not left when the solvent dries.

Fuel oil or Diesel may be used for cleaning ternal surfaces and other nonelectrical items. sure that after it is used it is dried thor-ughly; fuel oil (DA) does not evaporate read-. Do not use this on rubber products.

Carbon tetrachloride is used for cleaning ectrical contacts, slip connections, switches, stributor disks, and motor commutators.

With a dry, clean, sash brush, clean dust, aper lint, nonoily dirt, *etc.*, from around the pe-retaining lid, tape-feed roll, and tape lide. To clean oil, grease, or gummy deposits om the transmitter top plate, wipe with a ece of clean cheesecloth dampened with sol-nt (SD).

With a piece of clean cheesecloth moistened ith carbon tetrachloride, wipe off the contacts nd the contact screws. If a deposit of carbon found on any of the contacts polish lightly ith a contact burnisher. Be sure not to re-ove too much of the contact. These con-cts are made of a very soft material and, if are is not taken, they can be rendered useless.

Tape Transmitter and Distributor Electrical Troubles

The probability of electrical troubles in the ape transmitter is slight. When they do occur, owever, they present the same symptoms as o many improper mechanical adjustments. When a transmitter distributor is operating in n RTTY system, an open circuit in any lead rom the contact tongues to the distributor disk auses the impulse with which it is ssociated to be transmitted as a spacing im-ulse regardless of tape perforations. The open ircuit causes garble in the copy at the re-eiving equipment.

A break in a solder connection between the nds of the contact lever springs and the con-act tongues and terminals will cause opens in he signal circuit. Sometimes a resultant jitter nay be enough to garble copy at the receiving quipment. Only marking impulses are affect-d by jitter in an RTTY system.

When an open circuit occurs in wiring between the spacing (upper) contact screws and the spacing terminal on the slip connection block or terminal board (whichever is used), it has no effect on the proper operation of a transmitter distributor in an RTTY system, since the upper contacts are not used.

When there is an open circuit in wiring between the marking (lower) contact screws and the marking battery terminal on the slip connection block or terminal board, no current flows, and all receiving equipment runs open in a neutral system.

Excessive sparking and shorts between segments are the most common troubles in a transmitter distributor. Particles of metal and carbon may accumulate between ends of the segments and between the concentric rings on the commutator disk. If the accumulations become great enough to short the segments, false impulses are transmitted. If there are shorts in the concentric rings, steady marking signals are transmitted even though the message tape is passing through the tape transmitter, and the distributor brush assembly is revolving.

Brushes that are worn excessively or that are seating improperly can cause excessive sparking in the distributor; the commutator surfaces may be too rough or too grooved.

There can be varied types of motor electrical troubles because of the different types in use. However, the most frequent troubles are caused by worn or dirty motor brushes or worn and burned governor contacts.

An open may develop in any one of several parts of the control circuit (fig. 10.20). Check the stop magnet, the tape-stop switch, and the resistor. Sometimes the tight-tape stop contacts and the end-of-tape stop contacts get dirty and fail to close a circuit completely. The control circuit may extend through slip connections to another piece of equipment for the purpose of controlling the transmitter distributor in relation to the other equipment. Check such circuit extensions, especially whether proper connections are made. Check slip connections for dirty or bent contact springs.

Tape Transmitter Mechanical Troubles

If the tape fails to feed properly, remove it and inspect the feed holes to see if they are torn out or otherwise damaged. If the leading edges of the feed holes in the tape are pulled or torn, the feed roll is being turned before the tape pins are withdrawn from the perforations. Adjustment of the feed-lever adjusting screw to requirements will correct this trouble.

Improper adjustment of the operating lever adjusting screw can cause the tape to fail to feed or to feed partially forward and then return to its former position. The cause of this

type of trouble is failure of the feed pawl to move the feed roll ratchet far enough; a tooth on the feed roll ratchet moves forward such a short distance that it does not pass the center of the detent roller. This causes the feed roll to return to its former position by force exerted on a feed roll ratchet tooth by the detent roller. Correct this trouble by adjustment of the operating lever adjustment screw.

When tape fails to feed, it is an indication that the feed pawl is not engaging the teeth on the feed-roll ratchet, or that there is no motion imparted to the feed lever. Watch the motion of the parts while turning the main shaft by hand to observe which part fails to function. If the feed lever moves properly, the trouble is in the feed pawl. The feed pawl spring tension may be too little, the feed pawl spring may be broken, or the feed pawl or feed roll ratchet may be damaged. If the feed lever is not moving or is not moving a proper distance, the trouble may be due to improper adjustment of the feed lever adjusting screw, feed lever spring, or both. The feed lever adjusting screw may be so far back that the feed lever cannot raise the feed pawl enough to engage the next tooth on the feed roll ratchet. The tension of the feed lever spring may be so small that it cannot force the lower arm of the feed lever to follow the motion of the adjusting lever. If so, the horizontal arm of the feed lever cannot raise the feed pawl enough to engage the next tooth on the feed roll ratchet. Check that there are no broken parts.

Adjustments of the detent bracket and the retaining lid plate may be the cause of trouble. If improperly adjusted, the transmitter contact tongues will fail to make contact with the marking (lower) contact screws when a tape perforated with the LTRS combination is run through the transmitter distributor. When any adjustment of the detent bracket or the retaining lid plate is made, always check interrelated adjustments. Be sure that contacts are clean and aligned properly.

Check the alignment of the contact tongues when one or more of the transmitted code impulses never change regardless of the code perforated in the tape corresponding to that impulse. Contact tongues may be bent so badly that they do not leave contact screws against which they are supposed to rest, regardless of the position of the contact lever.

Trouble may arise from improper adjustment of contact screws. Some of these troubles include spacing (upper) or marking (lower) contact screws being too high or too low, or in any combination of high and low positions, set screws loose, contact screws missing or in such positions that their points cannot make contact with the contact tongues, and broken leads to contact lugs. Check for the conditions (exce loose set screws) by visual inspection. Try s screws with a screw driver.

Distributor Mechanical Troubles

A whining noise near the main shaft ge and the motor pinion can indicate improp positioning of the motor on the distribut base, or gears that are meshed too closely. sure that there is no bind between the mot pinion and the mainshaft gear, and that the is a minimum of backlash.

The stop arm may be positioned too high too low in its bracket, the stop-ar pilot screws may be either too loose or t tight, or the stop-arm spring may be broke or unhooked if the stop arm seems to be o of adjustment. When the stop arm is fixed t low in its bracket or the pilot screws and the bearings are badly worn, the upper edge the stop arm may be so low that the st arm does not bear on the stop cam b passes below it. If tape continues to feed, the brushes continue to revolve when the tigh tape stop lever is raised, or the tape-stop switc is opened, the stop arm may not be engagi the stop cam lug. Look for a broken or u hooked stop-arm spring, and check whether t stop arm is binding in its pivots so much th the stop arm spring does not move properl

Turn the main shaft until the operating lev roller just begins to ride up the high part the operating cam to check the position a adjustment of the main shaft. The main sha is too low if the operating lever bears again the operating cam at any part of its revolutio If the operating lever roller rides only the low portion of the camming surface of the opera ing cam, the main shaft is too high.

Wrong timing of contact tongues is cause by improper adjustment of the operating cam this can cause shortening of the No. 5 (t last) impulse in the code group. An indicatio of improper timing is given when a receivi teletypewriter turns out correct copy from transmitter distributor in a local test circu but produces garbled copy when signals a transmitted over a signal line of reasonab length.

Garbling can be caused also by wrong pos tioning of distributor brushes, the brush arm or both. The operating cam may be very lat its peak must be moved in the direction of r tation of the main shaft to bring it into corre adjustment. When the operating cam is ver late, the tape does not feed and the tape sen ing pins do not rise through the tape perfor tions until the distributor brushes have passe over approximately 60 percent of the start se ment. This does not affect impulses in t code group.

The operating cam may be very early; i

Condition	Probable trouble and remarks	Corrective action
Motor fails to start	Fuse in power supply burned out	Replace fuse.
	Fuse in associated equipment burned out	Replace fuse.
Motor runs but main shaft fails to turn.	Tape-stop magnet not energized	Check circuit.
	Stop arm not clearing stop cam lug when magnet is energized.	Adjust magnet bracket.
	Operating lever bent or adjusted so that operating cam cannot rotate.	Replace or straighten, and adjust.
	Friction clutch not exerting torque	Adjust and lubricate.
	Main-shaft gear teeth worn or missing	Replace.
Motor runs but tape-stop magnet not energized.	Tight-tape stop contacts dirty or out of adjustment	Clean. Adjust.
	End-of-tape stop contacts dirty or out of adjustment	Clean or adjust.
	Tape-stop switch defective or not thrown to ON (or SEND).	Check switch and its position.
	Control circuit wiring or parts other than above items (such as stop magnet, resistor, etc.) open or not strapped to power supply.	Check circuit.
Motor runs but tape-stop magnet vibrates on ac.	No. 86951 resistor not properly strapped (too much resistance); does not apply to Reperforator Transmitters TG-26-A and TG-27-A.	Check circuit.
	Terminal block not properly strapped (too much resistance); applies only to Reperforator Transmitters TG-26-A and TG-27-A operated on workbench.	Check circuit.
Motor runs and main shaft rotates but cannot transmit.	Signal line not connected, shorted, or open	Check circuit.
	Line current not furnished by associated equipment	Check line current supply.
	Distributor brushes not making contact with commutator segments.	Adjust; replace if worn.
	Contact screws and contact tongues dirty or not in adjustment.	Clean or adjust.
	Contact-lever springs broken, missing, or weak	Replace and adjust.
	Operating lever adjusting screw improperly adjusted	Adjust.
	Operating lever bent or binding	Straighten, clean, and lubricate.
Motor runs but only blank signal transmitted	Message tape perforated with feed hole only	None required.
	Tape-feed mechanism improperly adjusted so that the perforations are not above the tape pins.	Adjust tape-feed mechanism.
	Marking contact screws and contact tongues dirty or out of adjustment.	Clean or adjust.
	Contact levers binding so that they do not move when the contact-lever bail releases pressure on them; weak or broken contact-lever springs also may produce the same result.	Clean and lubricate or replace spring and adjust.
Motor runs but certain impulses are transmitted as marking impulses regardless of the tape perforations.	Contact-lever tape pin broken or missing	Replace contact lever and adjust.
	Marking contact screw tightened until there is no contact separation, or the contact tongue bent until it does not leave the marking contact regardless of the movement of the contact lever.	Adjust.
	Commutator segment shorted to stop segment; this usually is limited to No. 5 segment and the start segment; however, two or more may be shorted in a row. In the most extreme case all seven segments in the outer ring are shorted together which is the equivalent of an unbroken ring transmitting a steady marking signal.	Clear the short.
	Commutator segment; one or more shorted to inner distributor ring.	Clear the short.

Fig. 10.23—Model 14 TD trouble analysis chart.

Condition	Probable trouble and remarks	Corrective action
Motor runs but certain impulses are transmitted as spacing impulses regardless of the tape perforations.	Contact lever binding, or contact-lever spring weak or broken.	Clean and lubricate, or place spring and adju
	Marking contact screw with too much contact separation, or contact tongue bent until it does not make contact regardless of the movement of the contact lever; contacts may be dirty.	Clean or adjust.
	Leads between contact tongues and commutator segments open.	Reconnect the leads.
Motor runs but speed is erratic.	Governor contacts dirty or pitted	Clean, burnish, or repla
	Load-compensating circuit resistor open, or stop-arm contacts dirty or out of adjustment; contacts may be bent so that they fail to open.	Close circuit; clean a adjust contacts.
Transmitter distributor appears to transmit correctly but receiving machine runs closed and fails to receive.	Inner distributor disk ring shorted with stop segment	Clear the short.
Transmitter distributor appears to transmit correctly but receiving machine prints garbled copy.	Signal line partially shorted	Clear the short.
	Commutator start segment shorted with stop segment, resulting in the receiving machine starting too late to receive all the transmitted impulses of each character.	Clear the short.
	Operating cam maladjusted; No. 5 impulse may be garbled.	Adjust.
	Stop segment has open circuit between segment and marking contact screw.	Close the circuit.
	Motor speed is too fast or too slow	Check and adjust the motor speed.
	Gears: improper motor pinion and main-shaft gear being used.	Change to correct gea
Motor runs and main shaft turns but fails to stop.	Tape-stop switch shorted, or tight-tape stop contacts and end-of-tape stop contacts (when used) may be shorted.	Clear short.
	Stoparm spring broken, missing, or weak	Replace.
	Stoparm binding, bent or broken	Straighten or replace; a just and lubricate.
	Tape-stop magnet bracket improperly positioned	Adjust.
	Stop cam lug broken or worn	Replace.
Motor runs and main shaft turns but tape does not feed properly.	Detent roller and bracket improperly positioned	Adjust.
	Feed pawl spring broken	Replace and adjust.
	Feed pawl broken	Replace.
	Feed-lever spring broken, missing, or weak	Replace and adjust.
	Feed-lever adjusting screw improperly adjusted	Adjust.
	Feed adjusting lever missing	Replace and adjust.
	Operating lever adjusting screw improperly adjusted	Adjust.
	Operating lever bent or binding	Straighten, clean, and lubricate.
Motor runs and equipment transmits properly but produces a growling or whining noise.	Motor pinion and main-shaft gear improperly meshed	Adjust.
	Motor bearings not lubricated, binding, or full of grit	Clean, lubricate, and r place if necessary.
	Motor armature shaft bent	Replace armature.

ak must be moved in the opposite direction main-shaft rotation to bring it into correct justment. When the operating cam is very rly, the tape sensing pins are pulled down d the tape feeds when the distributor ushes have passed over approximately 30 rcent of the No. 5 impulse. If the No. 5 pulse is marking, this impluse is shortened to proximately 30 percent of its normal length. marking-to-spacing transition is produced by e movement of the contact tongue away from e contact screw during the time allotted to e No. 5 impulse and a spacing-to-marking nsition is produced by the movement of the tributor brushes on the stop segment at e end of the time allotted for the No. 5 pulse. Hence, the receiving teletypewriter ay select the No. 5 impulse incorrectly, be- use the impulse is shortened. Only the acing-to-marking transition by action of the tributor brushes occurs if the No. 5 im- lse is spacing, and this transition occurs at e proper time.

Wrong alignment of the brushes can affect e length of the Nos. 1 and 5 impulses of ch code group, because voltage may be aced across the Nos. 1 and 5 contact screws d the contact tongues during their operation.

With the old style tight-tape stop mechan- m, a loose set screw in the tight-tape stop aft collar generally causes trouble because ne of the tight-tape stop contacts fails to close, ereby resulting in the transmitter distributor iling to run. A frequent cause of trouble on e new style tight-tape stop mechanism can a loose clamping screw on the stop lever amp; the contacts open when the clamping rew becomes loose enough to allow the shaft turn in the clamp. Improper adjustment or mage to the contact springs and accumula- ons of dirt on contact points are other causes trouble.

Disk Servicing

The distributor disks may be serviced in the llowing manner. Remove the brush arm as- mbly by loosening the brush arm retaining rew. Wrap a piece of clean, dry cheesecloth round the main shaft and main shaft bracket elow the distributor disk to catch any parti- es of grit from sandpaper. Then wrap a iece of No. 000 sandpaper around a block f soft wood having dimensions of about 2 by by ¾ inches. Place the block on the dis- ibutor disk and press down with the fingers. evolve the block about the axis of the main haft; at the same time, avoid undue pressure any one point. As soon as the segments are lmost smooth, remove the No. 000 sandpaper nd replace it with No. 0000 sandpaper. Re- eat the finishing procedure until the surface f the segments are smooth and polished. Do not remove any more metal from the segments than is necessary. Remove any dust or metal particles that may have accumulated between the segments.

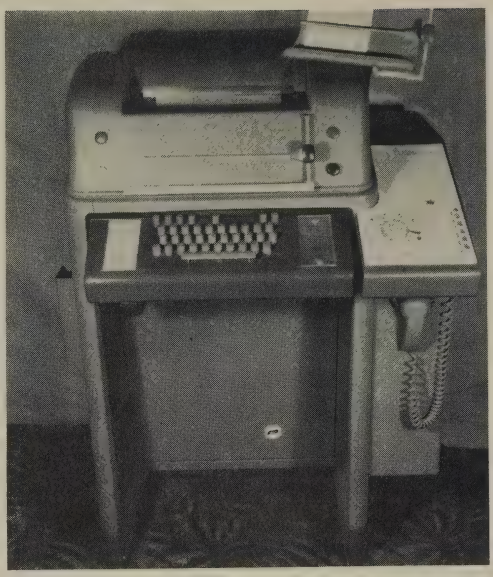


Fig. 10.24—General view of a Teletype Model 28KSR Page Printer, as set up for commercial use.

Particles from carbon brushes at times become imbedded in the surfaces of the copper commutator segments and cause them to become dark. The discoloration resulting is a form of case-hardening and greatly increases the life of the segments. Unless the segments are deeply grooved, do not remove this discoloration.

When the distributor disk is refinished, trim off any burrs that have formed on the ends of the segments. Such burs can cause the carbon brushes to chip or break pieces out of the braided copper brushes. A coat of insulating paint or varnish may be placed on the ends of the segments to prevent carbon dust or copper particles from shorting the segments. Do not allow paint to get on the upper surface of the segments where it could be picked up by the distributor brushes.

Trouble Analysis Chart

The analysis chart of fig. 10.23 lists troubles that occur most often with the Model 14 TD unit. In addition it gives the corrective action which may be taken.

Operating Checks And Adjustments

One may not always know the condition of the Model 14 TD that one acquires so it is a

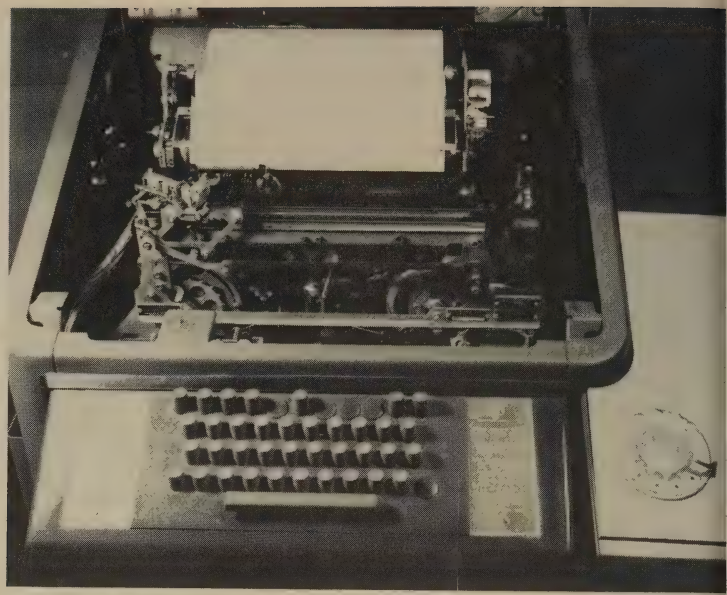


Fig. 10.25 — Close-up view of the Model 28K-SR with the cover hinged back.

good idea to *inspect it* before it is put into operation. It should be thoroughly cleaned and lubricated in accordance with the foregoing sections if these operations are required. In many instances they are in bad need of both. However, *never overlubricate.*

If definite information is lacking as to the exact condition of a unit, check the following parts to be sure that proper adjustments have not been changed:

Motor—Turn the motor by hand in the direction of normal rotation (distributor brushes moving clockwise) to make sure that there is no bind or excessive backlash between the motor pinion and the mainshaft gear, and that there is no bind in other parts of the equipment. Never turn the motor backward. To do so may cause the brushes to catch on edges of the commutator segments and consequentl break or bend.

Distributor Brushes—See that the brushes ar making contact with the commutator segment and that they have proper tension and positio with respect to the reference line on the dis tributor disk.

Tape Stop Arm—The tape-stop arm shoul clear the stop cam lug when the stop magne is held in its operated position, and the sto arm should engage the stop cam lug full when the armature is released.

Tape-Feed Mechanism—Put a piece of per forated tape in the tape transmitter. Then turn the motor by hand, in the direction o rotation, and observe whether the tape ad vances one full row of perforations for eac complete turn of the main shaft. If the tap moves either more or less than one full rov of perforations, readjust it to meet require ments.

Tape Sensing Mechanism—Put a piece of tap with repeated LTRS combinations on it in the tape transmitter and turn the motor as in structed above. Observe whether all the tap pins pass through the associated perforation in the tape. If a tape pin fails to pass through 'a hole, check for a bind in the associated con tact lever and readjust the lever according to requirements.

Control circuit—Make a check of the strap ping on the No. 86951 resistor and, if neces sary, arrange the strapping to meet require ments for the local loop power supply voltage

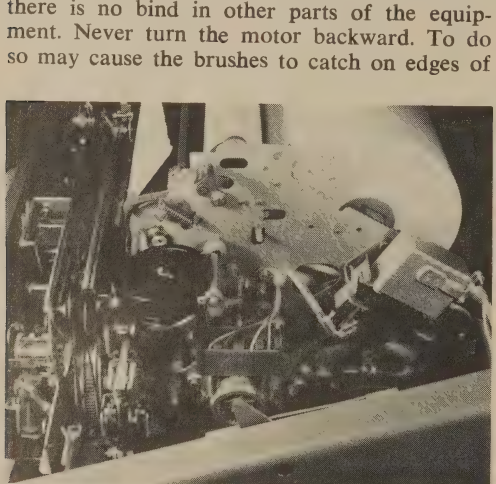
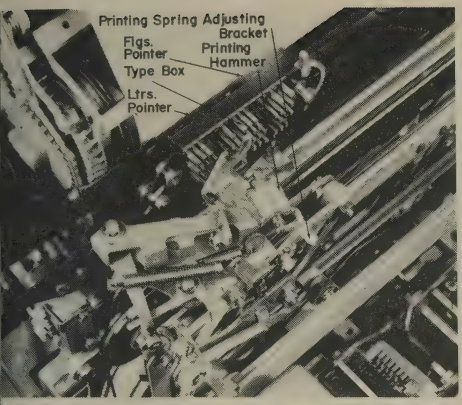


Fig. 10.26—Right side of Model 28KSR showing the motor, range finder and selector magnet.

TD Adustments

Information covering adjustments given in telephone company manuals is arranged in



g. 10.27—Close-up front left view of odel 28KSR showing type box and printing hammer.

quence that usually is followed by teletype-riter repair personnel when a complete re-ljustment of a transmitter distributor is un-rtaken. It is important that this be kept in ind by the repair or maintenance man be-use a change in a single adjustment may fect several other adjustments. When an ad-stment is changed, check all related adjust-ents.

Model 28KSR Page Printer

The Model 28 series of Teletype machines llowed Models 15 and 19 and are very much use, commercially. For this reason, the mber of these machines in amateur use is ll limited. Almost invariably, extenuating cir-mstances are involved in each acquisition ch as severe damage in shipment and some ligent amateur will spend weeks or months rounging parts and restoring the machine to rking order.

Figure 10.24 shows a general view of the odel 28 KSR (Keyboard Send-Receive) used the author for commercial purposes. Fig-e 10.25 shows a close up view of the ma-ine with the cover hinged back.

The Model 28 utilizes a three-row key-oard, as shown in fig. 10.25 and oper-es on a 5 level, standard communications de. The partial row above contains special rpose keys. Figure 10.26 gives a view of e right side. At the bottom, far right, a por-on of the synchronous motor may be seen. nmediately to the left of the motor is the nge-finder adjustment which is the wheel or linder-type knob. To the far left bottom may e seen the selector magnet coil. Figure 10.27 ves a close-up view of the top left front de of the Model 28KSR machine, showing e printing hammer and the type box.

Typing Unit

It should be recalled that, in the description of the Model 15 for instance, practically half or more of the machine was designated as the typing unit, containing a cumbersome "Basket" type carriage. The typing unit in the model 28 is essentially the *type box* and lightweight carriage with printing hammer shown in fig. 10.27. This typing mechanism weighs about one-tenth as much as the typing unit found in some of the older teletype-writers.

The type box dispenses with the traditional "type bars" found in ordinary typewriters and other teletypewriters. This feature alone does much to simplify and reduce the size of the Model 28 typing unit. In a broader sense, the selector mechanism, although isolated from the above-mentioned mechanism designated by Teletype as the "typing unit," is still a part of the typing unit as it was considered in the Model 15.

It is simple to completely remove the type box from the machine without tools. Once removed, it is easy to clean and service as well as replace with another type box containing special type or characters that one might desire.

The type box is moved from left to right, along in front of the paper on the platen, by the operation of the keys and/or space bar. Each key operation causes the type box to *move into the proper position* for the printing hammer to strike the proper character associated with that particular key thereby printing the character in its proper sequence on the paper. The type box is advanced *one character space* to the right with the printing of

Fig. 10.28—General view of the Teletype Model 28ASR machine.

each character or symbol or each time the space bar is pressed down. Operation of the CAR RET key at any time returns the type box back to its left-hand starting position and operation of the LINE FEED key advances the paper up to the next line.

Provision is made for making one to six (or more) carbon copies of the printed material. This is accomplished by adjusting the printing spring adjusting bracket to control the force of the printing blow.

Type Box

The type pallets in the type box are arranged in four horizontal rows. The face of these pallets can not be seen in any of the illustrations since they face the platen. However, the square extension bar from each pallet, protruding out the back of the type box, may be easily seen in fig. 10.27. The small rod from the printing hammer strikes the rear protruding square bar of the pallet of the letter, figure or symbol that is being printed. The type box is segregated with the letters (lower part of keyboard keys) occupying the left half and figures, *etc.*, (upper part of keyboard keys) located in the right half. This means that the Model 28 does not have the familiar up and down motion for shifting and unshifting operations that we are familiar with. The type box *shifts to the right for letters* and *to the left for figures.* Figure 10.27 shows the type box unshifted to the right for letters.

The type box frame has two pointer edges (letters pointer and figures pointer) protruding from its top toward the paper on the platen. These are hard to see but are identified in fig. 10.27. It will be noted that the "letters pointer" is *in line* with the end of the printing hammer. This means that the "letters pointer" not only points out the position where the next character will be printed but it also assures the operator that it will be a letter. Note that the printing hammer is aimed at the center of the *left side* (letters pointer) of the type box with the type box unshifted *right* as shown in fig. 10.27. When the type box is *shifted left* the *figures pointer,* located at the center of the *right half* of the type box, will be in line with the aim of the printing hammer. This indicates to the operator that any key depressed will print whatever is listed on the top half of the key which will be a figure or symbol. It becomes readily apparent, from the above, that the *letters pointer* and the *figures pointer* can be of material aid to the sending operator as he types out his message. A quick glance at the pointer over the next space, following the character just printed, indicates to him if a letter or figure (or symbol) will be printed next when he presses

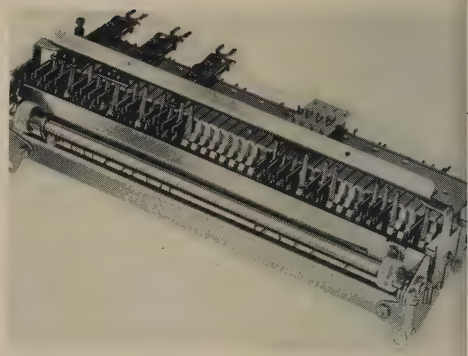


Fig. 10.29—Teletype's unique "stunt box

another key. The type box does have an and down motion but it for the purpose selecting whichever one of the four lines pallets that contain the letter, figure or symb that is to be printed.

In addition to the left shift for figures a symbols and the right unshift for letters, ce tering either the *figures pointer* or *lette pointer* in line with the printing hamme there is a momentary left or right excursi of the pointer position in the selection of character in a particular horizontal line of ty pallets.

Other Features Of Model 28KSR

Located under the cover is a line spa lever which may be seen protruding up fro the edge of the left end plate and next to t end of the paper roll. When pulled forwa the machine operates with single line spacin Pushing the lever to the rear of the machi provides for *double line* spacing.

Pressing the SPACE BAR or LTRS key w unshift the type box from the figures positio It is not necessary to press down the spa bar for each space if more than one spa is desired. The machine will continue to spa so long as the space bar is held down. Th feature is optional only. If figures or a symbols listed on the top half of any of t keyboard keys are desired following one more spaces it will be noted that *first* t FIGS key must be pressed down. This is b cause of the added *unshift* feature of the spa bar operation. This was the same situation associated with Models 14, 15 and 19.

As with the Model 14, 15 and 19, it good practice to begin a new line by pres ing CAR RET, LINE FEED and LTRS keys a in this order if the new line is to start wit letters. The FIGS key, instead of LTRS, shoul be the last key pressed if the new line is t start with a figure or other upper case cha acter.

The Model 28KSR has an end-of-line indicator warning light. The machine is usually adjusted for a line of 72 character spaces and can be made up of any combination of letters, figures, symbols and spaces. The end-of-line warning light turns on about six character spaces before the actual end of the line is reached. The light is turned off by the CAR RET key operation. The end-of-line indicator light may be seen in fig. 10.24 on the right-hand front of the hinged lid immediately above the cover release button.

It will be noted from fig. 10.25 that there is a partial fourth row of keys at the top that is supplied with function keys. One such key (center) is the HERE IS key. This is used in connection with your automatic answer identification in land-line service but it can also be used in amateur RTTY service for automatic RTTY identification.

Another function key in the top row (2nd from right) is the REPT key that can be used to repeat a character. To start the repeat operation of a certain character, the key of that character must first be depressed, then the REPT key. After this is done, release the character key, holding down the REPT key for as long as it is desired to repeat the character. This is a time-saver for a slow typist since the repeat typing speed is at the full speed that the machine is set for. In commercial applications this is usually 100 w.p.m.

Another noteworthy feature of the Model 28 line is the all-steel type of clutches used. The all-steel clutch gives a superior coupling and a more positive, slip-free operation when engaged and a no-load condition when idling. This is quite an improvement over the felt-type clutches found in earlier machines such as Models 14, 15 and 19.

Model 28ASR

The Model 19 counterpart of the Model 28 line is the Teletype Model 28 ASR (automatic send-receive). This marvelous "mouth-drooling" machine, like the 28KSR, is still used extensively for commercial use. Even the price of a used one (if you can find one) ranges from $700.00 up. A general view of the Model 28 ASR is shown in fig. 10.28.

The machine is provided with an ingenious device dubbed the 'stunt box" which greatly adds to the versatility and adaptability of the machine. A picture of the "stunt box" is shown in fig. 10.29. Some of the stunts provided for are: (1) Automatic carriage return for anyone who has left his machine for a moment and returned only to find that it has been printing mostly at the end of the line can appreciate this feature. (2) Automatic line feed—This feature prevents the machine from printing over a previously typed line. Automatic carriage return and line feed are two functions that operate at the same time. (3) Provision is made for setting up special stunts. A number of special accessories such as the pivoted tape sensing unit are available.

Model 32KSR Page Printer

The Teletype Model 32KSR page printer is an economy version or equivalent of the Model 28KSR. The price of the machine new is just about the price of a used Model 28KSR (about $400.00 and up). The Model 32KSR is designed for standard duty applications whereas the Model 28 machines were designed for heavy duty use as well as applications requiring a greater range of features. The Model 32KSR is built to put in a normal working day, but is not designed for constant 24 hour duty as the Model 28 is. A new machine should last the average RTTY'er indefinitely.

The Model 32 series, like the Model 28 line, is equipped with a three-row keyboard and operates on a standard communications 5 level code. The machine is relatively quiet, compact, and light, making it adaptable for portable use. The machine is adjusted for 72 character spaces per line (10 character spaces per inch) and 6 lines per inch (vertical spacing).

Model 32ASR

The Model 32ASR, like the Model 19 and 28ASR, is a page printer and has a tape punch as well as a tape reader. However, it does not have the versatility of being able to use the keyboard to punch a tape while receiving an incoming signal such as can be done with both the Model 19 and 28ASR machines. It does have a modest price of under $600.00 new, directly from Teletype Corporation. A general view of the Model 32ASR is given in fig. 10.30. Several types are available such as the type designed for the Bell Telephone system or Western Union. The communications type would be more applicable to amateur RTTY work.

Like the Model 28, numerous extras, or options, are available such as the automatic non-overline and automatic carriage features discussed under the Model 28 line.

The printer mechanism is different from any described up to this point. A *type-wheel* is used. It is in the form of a cylinder having the characters distributed around the circumference of the wheel as well as in vertical rows. Basically, it is the type box of the Model 28 that has been, in a sense, rolled into a cylinder. Its typing operation requires that it

Fig. 10.30—General view of Teletype Model 32ASR Page Printer with tape punch and tape reader. The 32KSR has the same appearance except that it has no tape punch and reader on the left.

be both rotated and positioned vertically in order to print a specific character. The actual printing is accomplished by a small hammer that drives the type-wheel and ribbon against the paper *after* the type-wheel has been properly positioned.

Distributor

The machine is provided with a printed circuit *distributor* which is the heart of the keyboard operation as well as the TD or tape reader. The distributor takes the place of the familiar transmitter mechanism associated with Model 14 and 15 keyboards. The mechanical tape sensing as used in the familiar Model 14 TD and the Model 19 is not used.

32ARS Features

The reperforator or tape punch, along with the tape reader, may be seen on the le hand side of the machine in fig. 10.30. T tape punch mechanism is operated from *printer selector* and *code bars*. This mea that the operator may elect to cut or not a tape only of what he is receiving and pri ing but he can not use the keyboard and ta punch mechanism to cut a tape during t time that the machine is typing an incomi message. Since the same one distributor is volved whenever one of the components op ates, the two components cannot operate inc pendently.

Automatic RTTY Station Identification

The answer back mechanism generates t start-stop code for the HERE IS key that c be used for automatic RTTY station identific tion. This is a real handy device which has code drum supplied with enough plastic tin to form a maximum of 22 coded characte With "DE W5VU CW K" for example, operator would have a few characters left ove

Automatic carriage return and line feed, s for a 72 character line, is available as optional feature. There is a repeat key whic operates similarly to the key discussed in co nection with the Model 28 line. Like the Mod 28, it has automatic unshift associated with t space bar.

Tape Back-Space Key

The tape punch unit is equipped with BACKSPACE key which is indispensible making corrections to tape as you punch At first thought it may puzzle the reader to what is done with the mis-punched hol since they are already punched and the cha have already dropped into the chad box. Yo simply back space to the mispunched chara ter (wrong combination of holes) and the press the "letters" key which finishes punch ing out the rest of the holes since the lette code has five holes (mark spaces). You ne press the proper letter key you should hav pressed in the first place if you were sendin letters. If the next character should have bee a figure, then you should press the back spac key, the letters key and the figures key i that order before you press the key for th figure you desire. Incidentally, the Mode 32ASR does not type on the tape since punches the chads free of the holes. The bo provided for catching the chads may be see in fig. 10.30 and is the long box extending down just under the tape punch.

11

CODES, DATA PROCESSING & ADVANCED MACHINES

HE ART of signaling is probably as old as the man race. No matter how elementary or mplete any such signaling system was, it re-ired a *code*. Actually then, codes are pro-bly as old as the signaling systems since any stem was useless without a code. The dis-very of electricity opened up new possibilities signaling. Many electrical systems of signal-g were devised. Likewise, many electrical des were devised along with the electrical gnaling systems. Some of the electrical sys-ms went back to sound while others used sual means of signaling.

Early in the game, with the development of ectrical signaling systems, the *Baudot* code as used in connection with a keyboard of ve keys. Each key represented a portion of the ve-unit Baudot code. Those five key functions rrespond now to the function of the five aracter forming mechanisms associated with e keyboard transmitter unit described earlier this text in connection with Model 14, 15 nd 19 teletype keyboards. Imagine how cum-ersome it must have been for an operator to anipulate the five keys in proper sequence pressing each key or not pressing it) in order to send one character and repeating this process for each character transmitted.

Many codes, types of coding systems, and transmission techniques have been developed during the past 50 years and most of the more practical ones had one thing in common, the *pulse*. Pulse modulation, in some form, was used.

Once a code is established and accepted the information must be transmitted and the method used is to modulate an r.f. carrier. Perhaps the type of modulation most common to the amateur is *pulse duration modulation* (p.d.m.) shown in (a) fig. 11.1. The reader will no doubt consider this to be plain c.w., although in telemetry circles the value of the information transmitted is usually determined by the *duration of the pulse*. Actually, c.w. might be considered as a combination of (a) and (d) discussed below. The reader should recognize (b) fig. 11.1 as a form of amplitude modulation which is *pulse amplitude modulation* (p.a.m.). Another type is *pulse position modulation* (p.p.m.) shown in fig. 11.1 (c). Then finally, there is *pulse code modulation* (p.c.m.) shown in fig. 11.1 (d).

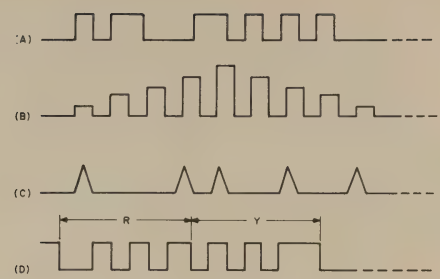


Fig. 11.1—Various types of coding modulations. (a)Pulse duration modulation (p.d.m.) (b) Pulse Amplitude Modulation (p.a.m.) (c) Pulse position modulation (p.p.m.) and (d) Pulse Code Modulation (p.c.m.).

Pulse Code Modulation

There should be no difficulty in recognizing the pulse code modulation wave shown in fig. 11.1 (d) as the *binary teletype code* which was discussed at the very beginning of this text. Under certain conditions pulse position modulation as shown in fig. 11.1 (c) may have a particular application, especially if power is a consideration. There are also conditions where types (a) and (b) of fig. 11.1 may be useful. Then too, there are still other types of modulation systems such as phase modulation and frequency modulation that have applications.

Of all the practical coding systems discussed, the pulse code modulation system is the most efficient. This is due to the *binary* nature of the code. A binary character or bit can have only one of two states. In mathematical language those two states are considered as *one* or *zero*. In data transmission language this is considered as a two-symbol system. In RTTY circles, they are thought of as simply ON or OFF or *mark* and *space*. The transmission of these symbols, one at a time is called *serial* transmission. Some times the term "baud" is used interchangeably or as a synonym for the term bit. This is an erroneous practice since the baud is a unit of signaling speed, as covered previously. The speed in bauds, for binary symbols, is the signaling rate in bits per second. (45.45 bauds for a speed of 60 w.p.m.)

A graphic relationship between the p.c.m. waveform and binary code equivalent of the decimal system is shown in fig. 11.2. This code system is advantageous because the *message carrying details* may be *increased* by simply *increasing* the *number* of *digits* in the *binary code*.

Timing

With digital representation of data, the elements of space and time both have significant roles that are inter-related. Obviously, symbols must be separated, one from another, in order

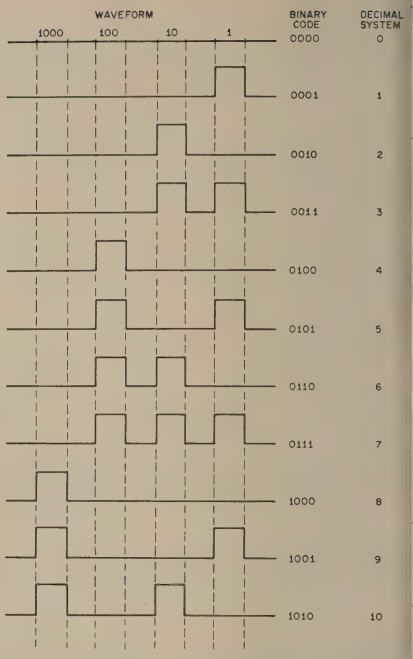
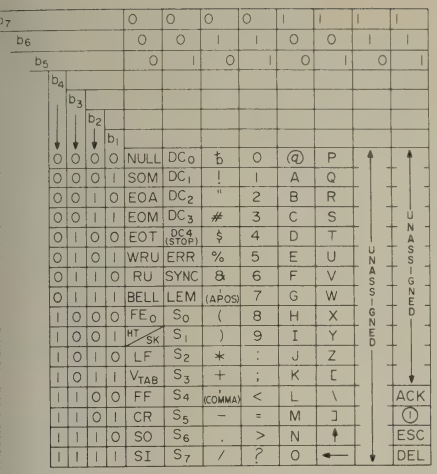


Fig. 11.2—Graphic relationship between t p.c.m. waveform and binary code equivale of the decimal system.

that they may be identified. Physical separ tion is used for printing, such as in this te Provisions for separation must also be includ in any electrical representation of symbols a system of signaling. Various methods ha been devised. One such method is the fix time pattern, better known as synchrono transmission and reception. With such a syste the receiving mechanism is in synchronism wi the time pattern of the received signal. The i formation capability and bandwidth of a p.c. system are both linearly proportional to t number of digits. One might say then that t *information capacity* is *proportional to t bandwidth* in such a system. This is based the assumption that the pulse width is fixed.

5-Level Code Limitations

It was pointed out earlier that with the 5-le code you can have a maximum of only code combinations. The binary nature of t code has already been discussed. At each le of the code there are only two possibiliti either there *is* a signal or there *is not* a sign There are five positions or "bits" where th condition exists. Therefore, $2^5 = 32$ maximu code combinations that one can have with 5-level code. There are twenty-six letters of t alphabet which use 26 of the 32 code combin tions. This leaves only 6 other code combin tions which are used for *machine functio* These functions were listed in the chapt



g. 11.3—The American Standard Code for information interchange.

vering in detail the operation of the Model and 15 machines. By using two of these as ft codes (letters and figures) we are able to uble our characters from 26 to 52 making it ssible to print all of the 26 letters of the habet, figures and a number of symbols.

We got along very nicely with the 5-level de, as outlined above, until data processing me along. With a printed message, a letter nsformation or mistake here and there usual- does not keep the correct interpretation m being made on the receiving end. In fact, plain language message has to be pretty well rbled to keep the person receiving it from at ast getting the general sense of the message. rtainly a missing letter here and there and en a word now and then does not detract om amateur RTTY work.

When sending coded messages or all figures, wever, an error can go unnoticed and as a sult can cause untold troubles, particularly the data transmitted is used in connection ith a computer. It becomes imperative that me practical means of checking accuracy be ailable under such circumstances. The 5-level de has too few code combinations for any rity check system to be built into 5-level code achines. Usually, 50 to 100 printed characters e required for today's business language. The -level code does not meet this requirement.

Other Level Codes

Adding one more digit to the 5-level code, aking it a 6-level code, doubles the code ination capacity from 32 to 64 ($2^6=64$). A -level code certainly adds to the capabilities f a teletypewriter but adding still another digit aking it a 7-level code again doubles the code mbination capacity, giving $2^7=128$. This al-

b_7	b_6	b_5	b_4	b_3	b_2	b_1
1	0	1	0	0	1	0

Fig. 11.4—The American Standard Code for the letter "R".

lows for many more special characters and symbols to be added to the machine. In all probability the engineer, with that many code combinations to work with, would designs into the machine a provision for some kind of parity check. Finally, an 8-level code provides for even greater possibilities including a parity check for error detecting purposes. An 8-level code makes it possible to have a machine that has both lower and upper case alphabet characters instead of upper case characters only that we are accustomed to with the 5-level code.

Accuracy Checking Systems

Various means have been used for accuracy checks. One method has been to transmit an additional figure which represents the *sum* of all of the figures transmitted in the message. This method will indicate, with a fairly high degree of accuracy, an error due to a mistranslated or dropped digit. Finding the error, after it has been discovered, can be time consuming.

Another system is the duplicate transmission method. This simply means the sending of the same message twice. If there is a difference between the two copies, the big question is, *which* is the *correct copy*? Resolving this question can also become time consuming.

Still another method that can be used on a 5-level code is to electrically count the *mark* "bits" of each word or group which, for a tape, means counting the code holes in the tape. One pre-decides that all such sum total values transmited shall be, say *odd*. If the actual bit count is not odd then an extra bit is transmitted to make it odd so that the totals at the receiving end will always be odd. One could have just as well decided to make all of the sum totals *even* by adding a bit if the actual count was odd and not adding anything if the count was already even. In binary code language, this simply means adding either a *one* or a *zero*. This is one form of *parity check*.

Redundant coding is another form of *parity checking* which may operate in any of a number of ways. Perhaps a trip to Webster's dictionary might be in order at this point. The words *redundant* and *redundancy*, to quote Webster, means "Excess, wordy, superfluous; using more words than are needed." Basically, this method involves the checking of those codes (characters) with say an *even* number of bits, or, if one so chooses, only the codes with an *odd* number of bits. Another variation of redundant coding is in the instance of a 6-level code where the

6th channel (or level) is used as a redundant code channel for parity checks. This method is also used with 7 and 8-level codes. With the 8-level code, the *fifth level* is used to make each character have an *odd number* of *mark bits*. In the case of a punched tape, it means that the number of punched holes for each character would *always* be *odd*.

In certain IBM data transmission systems, each character contains four space bits and four marking bits. This is called a fixed-count or "four out of eight" type code which provides for error detection.

Code Standards

Our discussion of codes has touched upon three separate but related fields: communications, data processing and last, but not least, telemetering. Actually, there are still other fields such as the printing business (automatic type setting) and animated devices in the advertising and amusement fields. Another application of codes is in the automation processes of many businesses. Apparently codes are here to stay and the machines and devices using them are expanding every day. It has been pointed out that, even in the communications field, there are variations in the standards. There are, for instance, different keyboard characters and configurations. Then there are the various machine speeds with different code pulse lengths. One can readily see that the problem of compatibility becomes more serious and more intolerable with time. There is a need for some semblance of standards, not only in the same area, but in related fields since there is considerable overlap between fields.

Unfortunately, it seems that as more equipment and systems came into being the number of *different* codes grew accordingly. If an accurate listing of all the various codes in the various fields was made, the number might reach 100.

The American Standards Association decided, a few years ago, that something in the direction of code standards should be worked out. Any code devised would have to be a compromise and at the same time be acceptable to all since it could mean the replacement or modification of existing equipment. In some instances this action could be deferred for a while or even indefinitely while in other instances it would mean that action would have to be taken soon. A committee was formed with representatives from the leading manufacturers of equipment, users and other data communications specialists organizations. After considerable work, a new ASA standard code was devised.

ASA Standard Code

As one would expect, the new ASA standard code is a multi-level code, an 8-level code, fact. The new code contains many improv features and it provides for many more chara ters. The American Standard Code for Infe mation Interchange is shown in fig. 11.3. Th coded character set is to be used for the gene interchange of information among data proce ing systems, communication systems, and ass ciated equipment. It will be noted that there a quite a number of blank positions in the co table that are designated as unassigned. The blank positions are available for future grow of the code as well as for special purposes.

The standard 7-bit set code positional ord and notation are shown with b_7 the high-orde and b_1 the low-order bit position in the examp of the code for "R" in fig. 11.4. Figure 11 gives the legend for the code and fig. 11.6 giv the character arrangement for the ASCII cod

NULL	Null/Idle	DC_1-DC_3	Device Control
SOM	Start of Message	DC_4(STOP)	Device Control (STOP
EOA	End of Address	ERR	Error
EOM	End of Message	SYNC	Synchronous Idle
EOT	End of Transmission	LEM	Logical End of Medi
WRU	"Who are you ?"	S_0-S_7	Separator (Informat
RU	"Are you....?"	b	Word Separator (spa normally non-printir
BELL	Audible Signal	<	Less Than
FE_0	Format Effector	>	Greater Than
HT	Horizontal Tabulation	↑	Up Arrow (Exponenti
SK	Skip (punched card)	←	Left Arrow (Implies/ Replaced by)
LF	Line Feed	\	Reverse Slant
V_{TAB}	Vertical Tabulation	ACK	Acknowledge
FF	Form Feed	①	Unassigned Control
CR	Carriage Return	ESC	Escape
SO	Shift Out	DEL	Delete/Idle
SI	Shift In		
DC_0	Device Control Reversed for Data Link Escape		

Fig. 11.5—Legend for the American Star ard Code.

Teletype Model 33 Line

In many respects the Teletype Model 33 lir is similar to the Model 32 line. Like the 3 it is designed for standard duty service. I appearance is similar to the Model 32 and it economically priced. The limitations of the Mo el 33 are essentially the same as those covere for the Model 32. The *real* difference betwee the Model 32 line and the Model 33 line star with their codes. As previously pointed out, th Model 32 and all other teletypewriters covere up to this point use the *five level communica tions code*. The Model 33 uses an *eight leve* message and data communications code. Th development of the Model 33 was probabl brought about more by the rapid growth of th data processing field than anything else. Wit the growth of the data processing field there be came a growing "equipment language" prob lem between the various devices and equipment used in the field. This equipment language i predominately digital in nature. As the dat processing field grew, it also became more an more evident that the five level code did no

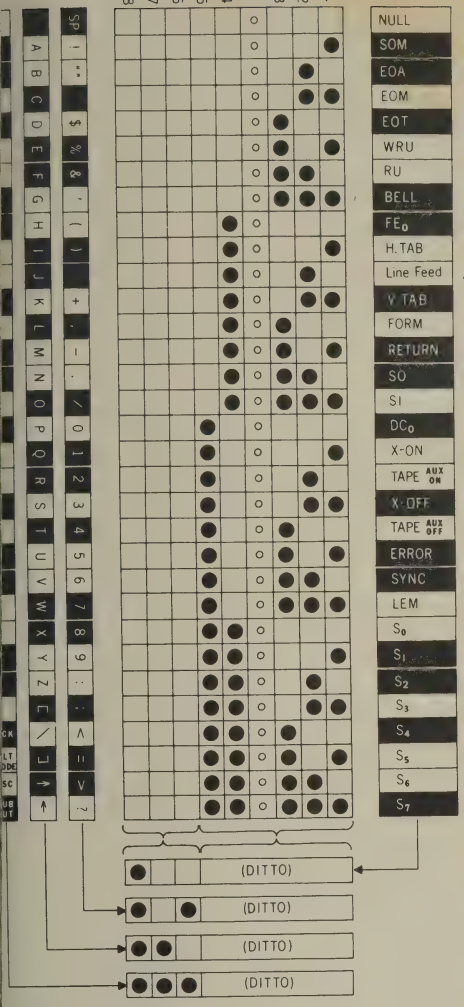


Fig. 11.6—Character arrangement of ASCII code.

rovide for enough characters and functions to o a proper job.

The Model 33 Teletype machine is available three different models. The simplest version the RO (Receive-Only) which is a page rinter. Next is KSR (Keyboard Send-Receive) hich is a machine consisting of a page printer nd keyboard. The other unit is the ASR (Au- matic Send-Receive) which is a machine con- sting of a page printer, keyboard, paper tape unch and reader. Other specification details re:

Page Printer—Horizontal spacing—10 char- cters per inch;

Characters per line—72 for pin feed or 74 or friction feed paper;

Vertical spacing—6 lines per inch (single) or lines per inch (double).

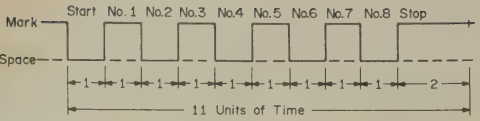


Fig. 11.7—Current wave form for letter "U" (with even parity) for teletypewriter 8-level code.

Keyboard—4 row ASCII (American Standard Code for Information Interchange).

Punch and Reader—8 level 1" wide fully punched paper tape. (Reader also accepts partially punched chadless tape).

Character spacing—10 characters per inch,

Feedhole position—Feedholes on same center line as code holes;

Feedhole diameter—.0465 inch,

Code hole diameter—.071 inch.

Operational Features—Speed—10 characters per second (maximum);

Code—7 level compatible with ASCII, 11.0 units, equal units (9.09 milliseconds) consisting of 1 start unit, 8 information units, and 2 stop units, as shown in fig. 11.7;

Parity—Vertical even—8th code level used.

Signal line input—20 or 60 ma with 48 to 240 volts d.c. line voltage and proper current limiting resistor.

An operational block diagram is shown in fig. 11.8 and the keyboard layout is shown in fig. 11.9. The shift and control characters generated on the Model 33 keyboard are shown in fig. 11.10. This also applies to the Teletype Model 35 covered later on in this chapter.

Teletype Model 33 Typewheel

Various teletypewriters have been covered which involved a number of different methods for printing copy. First there was the type basket (Teletype Models 14, 15, and 19), then the type box (Model 28) and type wheel (Model 32). The model 33 also uses a type- wheel. The character arrangement (as printed) of the Model 33 typewheel is shown in fig. 11.11. The actual type wheel is a small, light cylinder with four rows of characters, projecting from its surface. In operation, it moves with incredible speed and accuracy. In viewing fig. 11.11 one must visualize the cylinder as having been split down its side from top to bottom and flattened out as shown. The type- wheel has 16 vertical columns with four print- ing characters in each column.

The type wheel is divided into two fields designated as clockwise and counterclockwise for rotation purposes. In operation, the type- wheel rotates and moves vertically (for any one of the four horizontal rows of characters) in order to properly position the character to be printed.

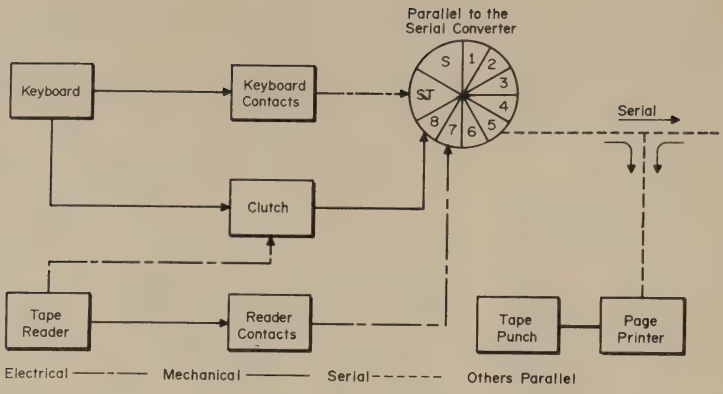


Fig. 11.8—Operational block diagram of the Teletype Model 33.

Direction of rotation is determined by pulse *four*. A spacing pulse causes the typewheel to rotate clockwise and a marking pulse causes it to rotate counterclockwise.

Each half (left and right) of the typewheel is further divided into two 4-column "fields" (left half—4 columns; right half—4 columns). The field (left or right) of the selected left or right half of the typewheel is determined by pulse *three*. Pulses one and two determine which one of the four columns selected will be moved to the printing area. Pulses *five* and *seven* determine which character (1, 2, 3, or 4) in the vertical column now in the printing area is to be moved into vertical position and printed.

It will be noted that pulse *six* is not actually used in any way in positioning the typewheel although it is actually transmitted and received the same as the other pulses. Pulse six can be used for other purposes such as performing stunt box functions.

Teletype Model 35

The Model 35 is built for heavy duty, constant use. Its versatility is almost unlimited in both the communications field and the data processing field. A general view of the Model 35ASR is shown in fig. 11.12. The Model 35 keyboard layout is shown in fig. 11.13.

Model 35ASR Modes

The Model 35ASR is equipped with a MO selector switch, shown in fig. 11.12 in the pan just to the left of the keyboard. The varic modes with the "on-line" and "off-line" co ditions are as follows:

K—On-Line—When the set is in the "Ke board" condition, the keyboard and prin can be connected to one or more remote uni The set acts as a send-receive page printer print all information coming in from dista sets, or going out from the keyboard.

K—Off-Line—The printer and keyboard a on an off-line circuit and cannot be connect to other units with an external signal line. Ho ever, the printer will produce page copy of information typed on the keyboard.

KT—On-Line—In the "Keyboard-Tape" co dition, all of the set's components are connect to an external signal line. The set can send formation from the keyboard and the ta reader to distant units. This allows variable formation of keyboard origin, and fixed infc mation from tapes, to be transmitted during t same call. The page printer and tape pun both record all outgoing and incoming infc mation.

KT—Off-Line—All the set components a connected on an off-line circuit. The read and keyboard can be used individually, or

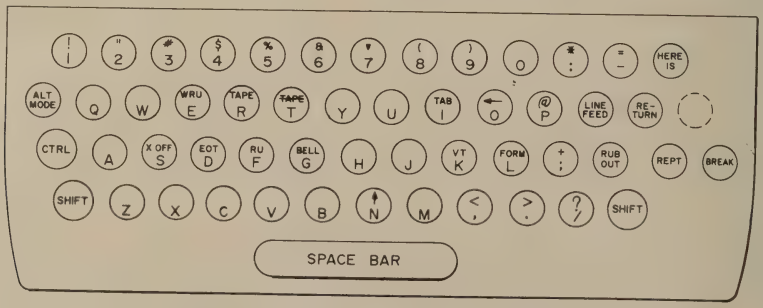


Fig. 11.9—Keyboard layout of the Model 33.

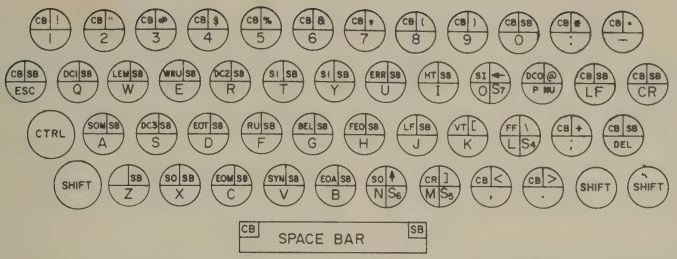


Fig. 11.10—Shift control characters generated on Teletype Model 33 and 35 keyboards.

mbination, to prepare page copy and punched pe.

T—On-Line—In the "Tape" condition, the ader and printer can be connected to distant iits over an external signal line. The inter monitors all incoming and outgoing in- rmation. At the same time, the keyboard and inch are on a common off-line circuit. They in be used to punch an independent tape.

T—Off-Line—The reader and printer are nnected on one circuit, and the keyboard id punch are paired on another. The latter o can be used to prepare a tape for input to nother business machine. At the same time, e printer can be producing page copy from eviously punched tapes to verify their accur- y.

TTs—On-Line—In the "Tape-to-Tape Send" ndition, the reader is the only unit connected the external signal line. The printer is blinded om receiving information and monitoring the ader's output. This mode is used to send reign (non-ASCII) 1-inch tapes of 5, 6, 7, 8 levels. The keyboard and punch are on a mmon circuit and can be used as in the "T" ode above.

TTs—Off-Line—Not applicable.

TTr—On-Line—In the "Tape-to-Tape Re- eive" condition, the punch is connected to an xternal signal line. It's used to receive foreign -level tapes, without the usual duplicate page opy being printed.

TTr—Off-Line—Not applicable.

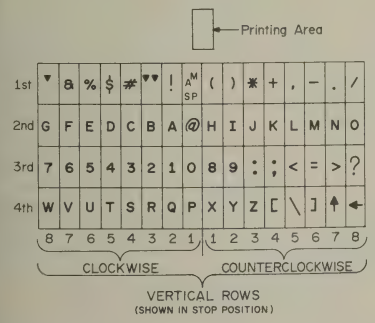


Fig. 11.11—The character arrangement (as printed) of the Teletype Model 33 typewheel.

Teletype Telespeed 100 EDC

The Telespeed 100 EDC, is a tape-to-tape, point-to-point system that can be used on private lines or the existing telephone network and operates at 100 words per minute (110 baud). The code is 8-level, 11.0 unit. Both terminals are equipped with unattended answering and answer-back features.

Provisions are made in the receiving set for comparing the data transmitted by the sending station. If an error occurs, the receiving station automatically requests a retransmission of the same information by the sending terminal. This is done by a tape pull-back feature in the sending station's tape reader. As the data is being sent by the transmitter for the second time, the receiver is deleting the first message containing the error. Erroneous messages are deleted at the receiver by a double punching device. The first portion of this mechansim punches the message and the second punches "rub-out" characters in the tape when necessary. The system automatically checks for error after a 72-character block has been processed. An automatic disconnet feature goes into operation if the 72-character block is not maintained, or if the tape runs out.

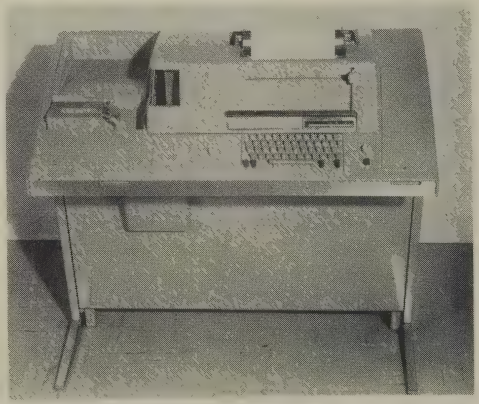
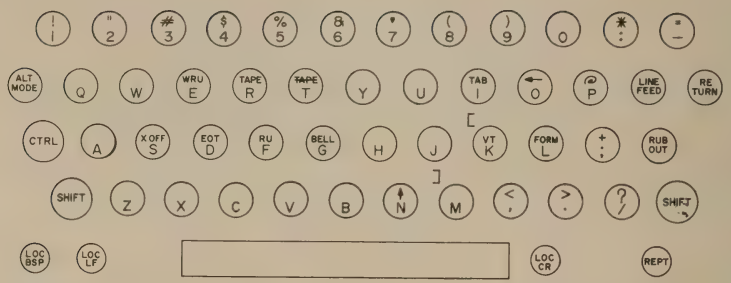


Fig. 11.12—General view of Teletype Model 35ASR machine



1. Depression of a key circled in BLUE together with the "SHIFT" key results in upper keytop graphic of that key.
2. Depression of a key circled in GREEN together with the "CTRL" key generates the control character associated with that key.

WRU	Requests remote station's identification and actuates its answer-back.
TAPE	Turns on remote auxiliary tape punch.
~~TAPE~~	Turns off local or remote auxiliary punch.
TAB	Horizontal tabulation to predetermined point of a line on the page.
X OFF	Turns off local tape reader.
EOT	End of transmission-terminates the call and turns off both machines.
RU	Conditions remote station to acknowledge its own identification code.
BELL	Rings signal bell at local and remote stations
VT	Vertical tabulation to a predetermined line on the page.
FORM	Automatic form feed to first printing line of next page.

Fig. 11.13—Keyboard layout and key functions of Teletype Model 35.

Teletype Telespeed 750

Telespeed 750 is designed for economical transmission and reception of data at speeds of 75 characters per second (750 words per minute). The 750 can be used as terminal equipment in a wide variety of data communications applications. For instance, with 750 equipment, a company warehouse can transmit its entire inventory of 7,000 items to the home office in minutes, using only ⅓ of a tape reel. The same list, typed single-space in tabular form, would be about 100 feet long and take hours to transmit manually.

Telespeed 750 sets can be used for data transmission, reception, or in a point-to-point data exchange for both data gathering and distribution. Many Telespeed sending sets at outlying locations can be used to report data to one receiving unit. In this way, the Telespeed receiver serves as a collection center. The punched paper tape output of the receiving set can be converted by other Teletype equipment to page copy, or used in various computers and business machines. The Telespeed sets will transmit the tape output of Teletype ASR (automatic send-receive) sets, self-contained paper tape punches, computers, and other business machines.

Telephone handsets can be added to Telespeed 750, providing normal voice communication that can be alternated with data transmission on the same telephone call. Telespeed 750 equipment is able to operate on any 5, 6, 7, or 8-level code. This includes the American Standard Code for Information Interchange (ASCII), which is the official language of many computers and other business machines. Thus, Telespeed equipment may be used to exchange data with a central computer. In some cases, such a computer can be equipped with auto matic dialing and a call directing characte signal generator, enabling it to automaticall poll outlying Telespeed sets to collect and dis tribute data without an attendant being presen This provides economical use of the line durin off hours or at night.

Teletype DRPE

The Teletype DRPE High Speed Tape Punch is a new concept in electro-mechanical punch ing devices, shown in fig. 11.14. This unique tape punch does not require energy from a motor to punch data into paper tape. Instead this energy is stored in a tuned reed while it is attracted to a magnet. The reed, a steel bar and its associated magnet and electronics are tuned to operate as a unit at a certain fre quency. A reed is linked to a punch pin for each code level. When the reed is released by

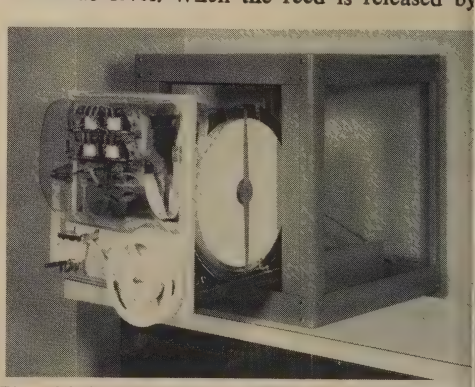
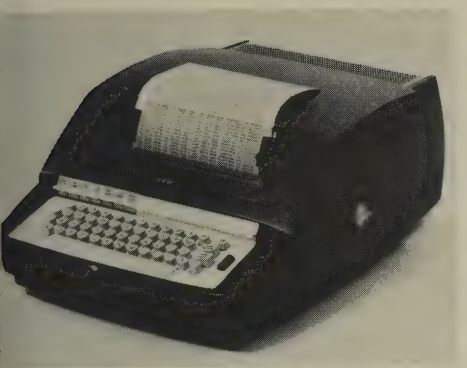


Fig. 11.14—Teletype DRPE tape punch mechanism, rack mounted, extended forward for better viewing.



g. 11.15—Kleinschmidt Model 311 high-peed communications and electronic data printer.

s respective magnet, the punch pin is driven hrough the tape.

The DRPE is capable of operating at any peed up to 2,000 words per minute (200 haracters per second) and functions in re-ponse to incoming parallel-wire signals. The nit is asynchronous and needs no adjustments r modifications when transmission speed is hanged and can be used for punching 5, 6, or 8-level codes in 11/16", 7/8", or 1" tapes. he DRPE's mechanisms are not in motion hile the unit is on line waiting for a signal. he net result is minimum maintenance and onger unit life.

Kleinschmidt Model 311

The Kleinschmidt Model 311, shown in fig. 11.15, is a transistorized unit with high reliability, requiring a minimum of maintenance. It has an input and output for computers, high-speed data transmission, and high-speed communications. The machine is compatible with existing 60, 75 and 100 w.p.m. communications. The manufacturer states that the machine will operate at a speed of 300 bauds maximum on a telephone channel for data communication and 150 bauds (200 w.p.m.) maximum speed over a telegraph line for telegraph communications. It would be a wonderful addition to anyone's set-up, amateur RTTY or otherwise.

311 Keyboard Mechanism

The Model 311 keyboards (3-row or 4-row) externally resemble those of electric typewriters. Internally, there is neither mechanical nor electrical connection between the keyboard and the printer. The depressed typing key lowers an individual coded keylever that rotates (a) one to six code bails, and (b) a universal bail. A magnet at the end of each bail controls a separate, glass sealed reed switch to indicate (a) for a code bail, the corresponding information bit of the typed character, and (b) for the universal bail, the fact that a character has been typed.

In the standard Model 311, the mechanism reed-switch output plugs into the printer chassis to utilize the electronic output located either within the printer package or in a separate electronics package. As an option, the keyboard mechanism can be completely separate from the printer chassis in systems not requiring an output other than the reed switch closures. The

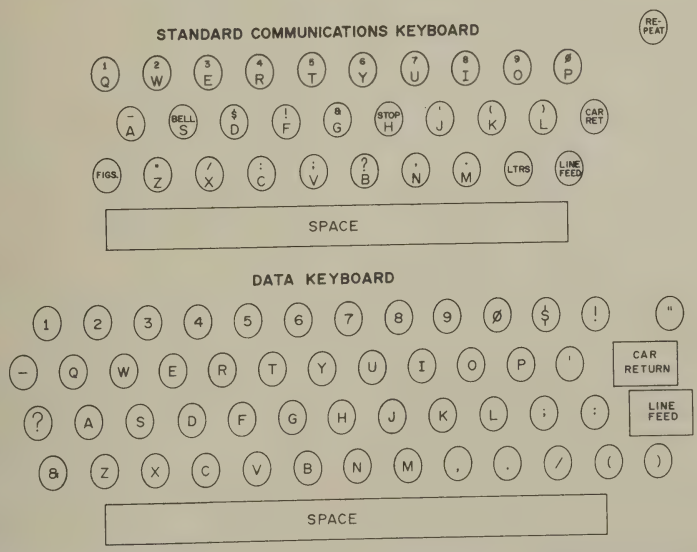

STANDARD COMMUNICATIONS KEYBOARD
REPEAT
Q W E R T Y U I O P
A BELL S D F G STOP H J K L CAR RET
FIGS. Z X C V B N M LTRS LINE FEED
SPACE
DATA KEYBOARD
1 2 3 4 5 6 7 8 9 Ø $! "
– Q W E R T Y U I O P ' CAR RETURN
? A S D F G H J K L ; : LINE FEED
8 Z X C V B N M , . / ( )
SPACE

Fig. 11.16—Three and four row keyboard arrangements available for Kleinschmidt Model 311.

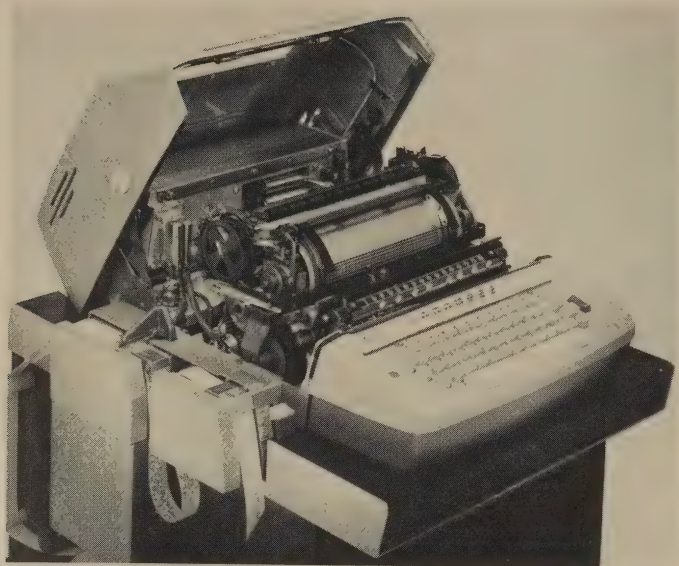


Fig. 11.17 — Kleinschmidt Model 32 ADS high speed automatic data set consisting of a send receive page printer paper tape reader and paper tape punch

keyboard can be locked either (a) mechanically by a LOCK-SEND switch on the keyboard, or (b) electrically by a lock solenoid. In serial signaling systems, 2-character bursts can be typed that exceed the line rate. The second character is stored in the reed switches while the first is being sent to the line by an electronic parallel-to-serial converter.

311 Printing Mechanism

The printer mechanism is a separate module that includes: (1) a continuously rotating type drum and a driving motor. The drum consists of 36 2-row type wheels joined together on a common shaft. There are 64 character positions around the type drum. The embossed characters are in binary order according to the corresponding Baudot code. Letters characters are on one half of the drum circumference and figures characters are on the other half. (2) A perforated clock wheel attached to the type drum shaft. The 64 perforations are monitored by a coil that supplies 64 character-position pulses to the input electronics. (3) A one or two hammer carriage that is stepped across in front of the type drum. The low mass, high velocity hammers are driven into the type drum by coils controlled by the input electronics. For carriage return, the carriage is belt driven to the left under control of a magnetic clutch. This action winds a spring which is used to step the carriage to the right under control of a space solenoid, space rack, and a pawl. (4) A continuously stepped ribbon mechanism with an automatic reversing feature. A ribbon vibrating mechanism is included to allow the last character printed to be visible in systems where the printer receives from a keyboard. (
A solenoid-triggered line feed mechanism po
ered by the printer motor. Single or double li
feed can be selected by a lever on the mec
anism. The mechanism can also be set f
either friction or sprocket feed. Space for
paper roll is available within the printer mec
anism. Fanfold paper must feed into the ba
of the printer cover from an external supply bo

Kleinschmidt Model 321ADS

The Kleinschmidt Model 321ADS, shown
fig. 11.17, is a high speed automatic data s
with a speed up to 37.5 characters per secor
It is compatible with data processing syste
utilizing speeds up to 375 w.p.m. or wi
conventional telecommunications equipment
standard operating speeds of 60, 66, 75
100 w.p.m. The keyboard and printing devic
on the Model 321ADS are identical to thc
found in the Model 311 just discussed.

Model 321ADS consists of a send-recei
page printer, a paper tape reader, and a pap
tape punch. It receives on-page copy or punch
paper tape and transmits automatically frc
the tape reader, or manually from the ke
board. The controls of the ADS printer a
completely electronic and the unit features
17-position mode panel for additional conti
purposes. Compact electronic components in t
printer replace bulky mechanical parts normal
used in standard electro-mechanical teletyp
writers, which results in greater equipment
liability and cuts maintenance requirements.

The printer accepts either sprocket-fed fa
fold paper, with storage facilities in the tab
or friction-fed roll paper installed in the un

321 Tape Reader

The Tape Reader, located on the left side of ADS Printer, is a compact unit which fea- es mechanical and photo-electric sensing for ding perforated chad or chadless tape. De- ned for start-stop operation at speeds in ex- s of 40 characters per second the Reader adaptable to 5, 6, 7, or 8-level tapes and ommodates 11/16, 7/8, or 1 inch wide tape, specified by the operator. Electronic start- p and operational controls for the Tape ader are located on the Printer Mode Panel.

321 Tape Punch

The Paper Tape Punch, located directly be- d the ADS Tape Reader, fully perforates 5, 7, or 8-level paper tapes. Adjustable tape des on the unit permit the use of 11/16, 8, or 1 inch wide paper tapes. Controls for Tape Punch are located on the ADS Printer ode Panel. The punch functions on a start- p basis at speeds exceeding 40 characters r second. The unique design of the punch ables the unit to use low speed shaft rotation sulting in quiet and smooth operation.

321 Electronic Logic Module

The Electronic Logic Module utilizes printed cuit boards which provide the logic circuits cessary for control of the Printer, Tape Read- and Tape Punch. This module is located the rear of the ADS table. Space is available the module for installing additional circuit ards for optional features such as Form Feed, ertical Tab, and Motor Stop. This provides e ADS with maximum flexibility for various pes of installation. The printed circuit boards e keyed to insure proper installation, and the terchangeability of the boards keep main- nance at a minimum. Operating speeds of the DS are selected by a switch located on the ne base printed circuit board. Speeds not ovided for by switch selection may be gotten y changing the board.

Friden Teletypewriters

Friden, Inc., of San Leandro, California, a bsidiary of The Singer Company, manufac- res an extensive line of teletypewriters, com- unications, data processing and other business achines under various trademarks such as: Flexowriter," "Justowriter," "Teledata," "Pro- ramatic," *etc.* The machine most adaptable to mateur RTTY work is the Friden Model FC lexowriter, or the Model FPC-5, 3-bank (rows f keys) Programatic Flexowriter, shown in fig. 1.18. It uses the 5-level code and is a heavy- uty page printer with the ability to punch a -level tape as a byproduct of the page printer peration, and to read 5-level chad or chadless pes. This model is designed especially for busi-

Fig. 11.18—Friden Model FPC-5, 3-Bank (3 rows of keys) Programatic Flexowriter.

ness systems use where the application involves 5 level code tape communications. It has the ability to be programmed, enabling it to automatically write all constant non-variable information on the form, to automatically control all horizontal and vertical line spacing and to automatically control tape punching. It has the further ability to connect an auxiliary Punch ing Unit, and automatically control the punching of two tapes independently of one another.

Another version of the Flexowriter is the Model FPC-5, 4-bank, which is essentially the same as the FPC-5, 3-bank, except that it contains four banks of keys, making its keyboard more nearly like a standard typewriter keyboard.. All keys are interlocked, so that the '1' key, for instance, cannot be operated while the Flexowriter is in a LETTERS shift condition. No alphabetic key can be operated while the Flexowriter is in a FIGURES shift condition. This feature eliminates the special training necessary for the average typist to operate a communications keyboard.

IBM Machines

Machines produced by IBM fall more into the classification of business, data processing and computer fields, rather than communications. For this reason, they use semi-rigid punched cards and magnetic tape, rather than punched paper or mylar tape for storing information used in the communication field. Printing of information is the same, however. The IBM 2203 printer can operate at speeds up to 425 lines per minute.

There is every possibility that magnetic tape could replace the punched tape in the communications field in the foreseeable future. One advantage would be the money saving on tape, since the magnetic tape can be used over and over again. Also, magnetic tape would allow faster transmission.

Multi-Level Codes And The Amateur

The foregoing discussions of multi-level codes and the associated equipment is enough to make some amateurs feel that we are back in the spark coil days so far as RTTY is concerned. To the contrary, the 5-level code and the associated machines designed for this code will serve the needs of the average amateur RTTY'er for a long time to come.

Actually, the growing sophistication of commercial teletype apparatus should be of help. The number and variety of machines that are obsolete for commercial use should rise sharply. This means that more and more machines will become available for amateur use. This should, in turn, help the commercial field.

The rapid expansion of the communication, data processing and telemetering fields and the subsequent growing application of the same techniques in many other fields means that many thousands of technicians, engineers and other people must be trained to design, build, operate and service the equipment. This reasoning has a familiar ring to it. This will not be the first time that the amateur has become a source of talent for commercial recruitment.

As the amateur ranks of RTTY grow, t enterprising amateur will, invariably, devise genious innovations that the commercial peo never even thought of.

Many of the 5-level code teletype machir available to amateurs can be changed fr the present 60 w.p.m. speed rate to 75 w.p. or even 100 w.p.m. by replacing gears change the speed drive ratio. It would appe that this would be the first logical step f amateur RTTY. The speed could first stepped up to 75 w.p.m. and then eventua to 100 w.p.m.

As time passes, there is no doubt but th the amateur will follow closely in the footste of those in the commercial field in the u of higher level codes. One has only to lo back to the passages of this chapter, coveri the various code levels and associated machin to realize the tremendous field of experiment tion that would be available to the amate using these codes. No doubt a closer look the technical equipment and technique a vances outlined here can produce some ide for the amateur searching for improvemer associated with the equipment presently allow by the FCC regulations.

12

DISTORTION PRODUCING TEST SETS

CONSIDERABLE attention has been focused upon the subject of distortion throughout this text. Distortion, without question, is the *number one* problem associated with RTTY work. This chapter deals exclusively with various machines, designed and manufactured for the express purpose of generating teletypewriter signals, with or without distortion.

Why A Distortion Producing Device?

It might appear, to the uninitiated, that distortion generating machines would be somewhat superfluous, considering the fact that there are already probably more distorted RTTY signals around than there are distortion-free signals. It has been pointed out repeatedly that every operator should determine without a doubt that his transmitted signal is free of distortion. It would improve conditions considerably if all amateur radio RTTY signals leaving the radio transmitter were free of distortion. Even if this utopia were an actuality, there would still be distortion at the receiving end under certain circumstances discussed earlier (and to be covered in greater detail later).

Invariably, wherever there is RTTY, there is also distortion and there is no choice but to cope with it. From all of this, it would appear that the receiving equipment should be so adjusted that it will continue to function in the face of as much distortion as possible.

One of the most practical ways of being able to adjust a teleprinter machine so that it will accept the maximum amount of distortion in the received signal is to have available a signal containing known or measurable amount of distortion.

Various devices have been developed for generating a signal with a controlled amount of distortion. With such a machine, one can effectively determine the error-free copying capabilities of a teleprinter. One can also make systematic adjustments to the teleprinter and immediately determine the results. The object is to adjust the teleprinter so that it will continue to copy a signal with the highest percentage of distortion possible. A poorly adjusted machine, or one needing cleaning or lubricating, may start making errors when only a small percentage of distortion is present in a received signal. On the other hand, a good clean machine, properly lubricated and adjusted, may correctly copy a signal with as much as 35 per cent distortion present under certain conditions.

It will be shown in Chapter 13, covering the regenerative repeater, that there are instances where a properly adjusted machine may start

making copy errors in the presence of as little as 25 per cent peak distortion. This is due to the fact that the stop-start system of synchronization is based on the sampling of only one (a particular one) transition in each transmitted character. There can be a deterioration (distortion) in this reference transition during the transmission of the rest of the elements or bits of the character. From this, it would seem that there are disadvantages in attempting to adjust a machine by using a received "off the air" signal known to have distortion, even if one had a means of measuring and knowing what the distortion content was. This is all the more reason that a device capable of generating a teletypewriter signal containing distortion, such as those covered in this chapter, should be used in adjusting a machine to accept the maximum amount of distortion before errors occur. When this has been done, the teletypewriter should be left alone and one should look to the use of other devices and techniques in an attempt to further improve copy in the face of distortion.

TS-659/UG Test Set

The TS-659/UG Test Set has a number of names. For instance, the Bell System name for a unit supplied with a 115 volt a.c. 60 cycle synchronous motor and a set of gears for 368 operations per minute is 100A Teletypewriter Test Distributor and the Teletype name for this same unit is ED51DT. The Bell System 100C is the same, except for a 50 cycle motor and proper gears for 368 o.p.m. The Teletype nomenclature for this last unit is ED51EH.

All Teletype Model ED51's have 115 volt a.c. 50 or 60 cycle synchronous motors, and the motor switch is in the power cord. Their Model ED58 is supplied with a 115 volt a.c., 25 to 65 cycle governor motor, and the motor switch is on the unit. A unit designated as ED58HE means that it is supplied with three sets of gears for 368 o.p.m. (60 w.p.m.), 460 o.p.m. (75 w.p.m.) and 600 o.p.m. (100 w.p.m.) respectively. The TS-659/UG discussed here is essentially the ED58HE listed above. About the only differences in the various models are those listed above.

The unit is housed in a metal case with a carrying handle and measures about 5" × 7" × 8¾". The entire set weighs about twelve pounds, with the major part of the weight in the motor. The unit is supplied with a wiring chart glued to the inside of the lid. It will be noted from fig. 12.1 that there is also a small card inside the lid which states that the set was calibrated at 60 w.p.m. and that extra gears are packed inside. The other gears are for speeds of 75 w.p.m. and 100 w.p.m. The wiring chart is a handy reference; however, its small size, considering all of the data it contains, certainly leaves something to be desired.

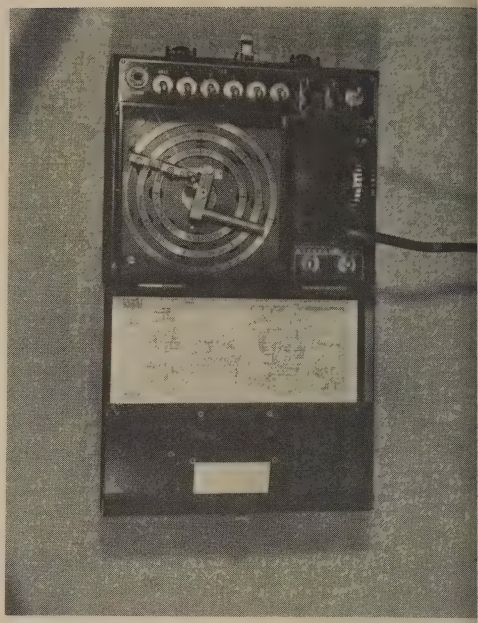


Fig. 12.1 - Top view of TS-659/UG portable signa distortion test set. The three bottom left han switches are referred to in the text as X, Y and Z

Figure 12.1 shows a top view of the set wit the case lid swung back. This lid can be readil slipped off the hinge pins for greater flexibilit while the set is in use. There is an additiona lid with a glass top that fits over the distributo portion of the set. This lid can also be hinge up and to the back, although it does not detac as the case lid does. It is shown in place in fig 12.1 and should certainly stay in place at al times except when cleaning, lubricating or oth erwise servicing this portion of the machine The motor should never be turned on whe this lid is up.

The distributor plate, the three distributo rings, the distributor arm and brushes can b seen in fig. 12.1. The extended rod from th distributor arm, on the opposite side from th brush holder is a counterbalance. With 368 o more o.p.m. the distributor arm goes aroun several times per second. Without the counter balance the arm would be subject to vibrations excessive wear of bearings and erratic opera tion.

The distributor brush circuit (signal line) a well as the power leads are supplied with filters The signal line filter may be placed in the cir cuit or out by the switch designated FILTER This is to minimize any r.f. interference from the set. The power cord is supplied with a three prong type a.c .plug with the third terminal fo ground.

The unit is normally wired at the factory fo

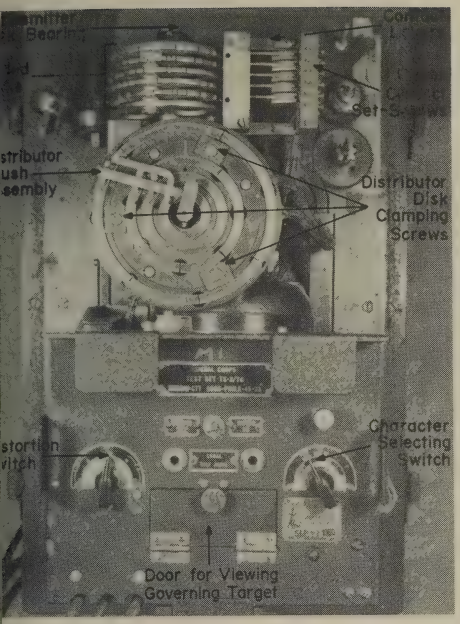


Fig. 12.2 - Top view of test set TS-2/TG

to 65 cycle operation. A series tapped resis- is supplied for operation at other power urce frequencies, such as 25, 40, or 50 cycles. iis is done by moving the power lead to the propriate tap on the series power resistor.

The a.c. power is only for the supplying of wer to the driving motor. D.c. power for the nal line is supplied externally and is that ltage used in connection with the operation a teletypewriter selector magnet being ad- sted. It could well be the operators local loop pply voltage.

General

This or any other such device must first be pable of generating or producing a teletype gnal that is reasonably free of any distortion. o this distortion free signal one must be able add controlled, fixed and known amounts of stortion of various kinds. One is capable of ing the following with this instrument: ansmit either of *two* kinds of *repetitious gnals* which are: (a) *Telegraph reversals* or,) *Teletype signal combinations.*

The telegraph reversals constitute an on-off gnal in which all pulses are equal in length. iis is an excellent source of square waves, sentially free of distortion, for testing filters, lar relays, *etc.* No distortion can be added this signal.

The repetitious teletype signal combination n be for any of the alphabet characters, or her teletype code combinations of the 5 level leprinter communications code.

These two types of signals (a and b) may each be generated (one *or* the other) free of distortion or 20 per cent distortion may be added to only the teletype signal combinations (b). The 20 per cent distortion can be either *bias distortion* or *end distortion.* There is the further choice of adding the distortion (one or the other) to either the marking pulses or to the spacing pulses. One is able to do all of these things by manipulating the numerous switches shown in fig. 12.1. The signal output jack is shown on the extreme right.

Distributor

The two types of signals described above are produced by the three concentric segmented rings on the distributor plate. The telegraph reversals are produced by the inner ring which has eight segments of equal length. This is the only function of this ring.

Both the middle ring and the outer ring have seven segments. The seven segments in each ring correspond to the seven segments of the 5-level teletype code. (A start segment, 5 intelligence or code forming segments and a stop segment.) These two rings are used for forming any desired test character. The segments in the middle ring are offset 20 per cent of a *unit impulse* with respect to the segments in the outer ring. They were so arranged in order to create and transmit either 20 per cent bias distortion or 20 per cent end distortion.

Control Switches

The control switches can be seen in fig. 12.1. The upper left switch labeled MOTOR is the motor on-off switch. The FILTER switch, to the right of the motor switch, gives the operator a

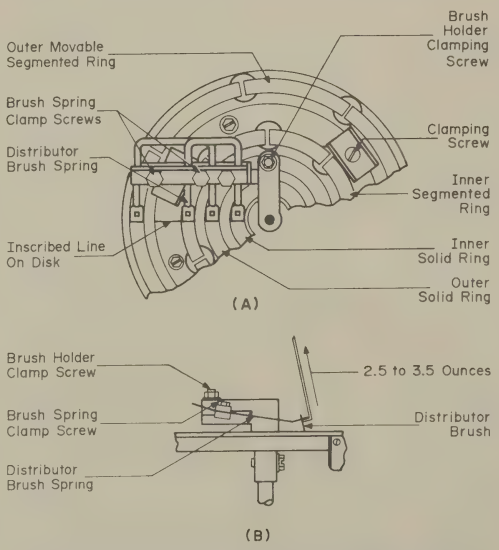


Fig. 12.3 - Distributor brush and brush spring.

choice of inserting an r.f. interference filter into the signal line if necessary. The signal pulses will have a sharper cut-off with this switch in the OUT position.

The signal control switches are those shown in a row along the front of the test set in fig. 12.1. There are 9 control switches which are mounted on a panel extending across the width of the test set. With the switch panel facing the operator, the first three switches from left to right will be referred to as *X*, *Y*, and *Z*; the remainder as 1, 2, 3, 4, 5, and STOP a inscribed on the panel. The position of th switches, front or rear, will be referred to a Front, Rear, or Center. The functions of th switches in the positions indicated are at left

X	**Front** - Telegraph reversals (RS)
	Rear - Teletype signals (TTY SIGS)
Y	**Front** - 20% End Distortion signals.
	Center - Closed loop condition (regardless of other keys).
	Rear - 20% Bias signals.
Z	**Front** - Spacing signal distortion.
	Center - Zero signal distortion.
	Rear - Marking signal distion.
1	**Front** - Spacing for first signal impulse.
	Rear - Marking for first signal impulse.
2	**Front** - Spacing for second signal impulse.
	Rear - Marking for second signal impulse.
3	**Front** - Spacing for third signal impulse.
	Rear - Marking for third signal impulse.
4	**Front** - Spacing for fourth signal impulse.
	Rear - Marking for fourth signal impulse.
5	**Front** - Spacing for fifth signal impulse.
	Rear - Marking for fifth signal impulse.
STOP	**Front** - Disconects Stop impulse.
	Rear - Connects Stop impulse.

Seven different types of signals may be ob tained by positioning the switches in as man combinations. These combinations, using th above designations, are as follows:

(A) Reversals
- X — Front
- Y — any position except center
- Z — Center
- 1 through 5 — Rear
- STOP — Rear

(B) Normal Undistorted Signals
- X — Rear
- Y — Rear
- Z — Center
- 1 through 5 — any position
- STOP — Rear

(C) Marking Bias
- X — Rear
- Y — Rear
- Z — Rear
- 1 through 5 — any position
- STOP — Rear

(D) Spacing Bias
- X — Rear
- Y — Front
- Z — Rear
- 1 through 5 — any position
- STOP — Rear

(E) Marking End Distortion
- X — Rear
- Y — Front
- Z — Rear
- 1 through 5 — any position
- STOP — Rear

(F) Spacing End Distortion
- X — Rear
- Y — Front
- Z — Front
- 1 through 5 — any position
- STOP — Rear

(G) Short Circuit Line
- X — any position
- Y — Center
- Z — any position
- 1 through 5 — any position
- STOP — any position

Test Set TS-2/TG

Test Set TS-2/TG shown in fig. 12.2, is teletypewriter signal distortion test set that capable of sending normal or distorted signa for testing teletypewriter circuits and equi ment. It is similar in some respects to the T 659/UG just discussed and is also manufacture by Teletype. Both have a distributor pla equipped with concentric segmented ring

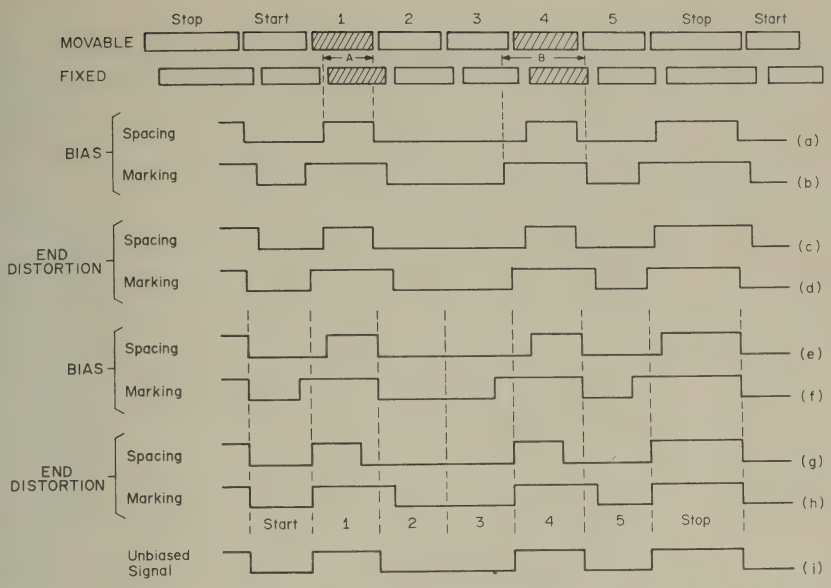


Fig. 12.4 - Examples of distorted signals.

heir similarity ceases at this point. The TS-9/UG is more of a portable test set with a xed amount of bias (20%) that can be in-rted into a circuit and the TS-2/TG can sup-y an adjustable amount of signal bias or end stortion from 0 to 50 per cent, either marking spacing. It is used to determine operating argins of start-stop teletypewriter mechan-ms and to test the efficiency of the selecting echanisms in teletypewriter selector units. he TS-2/TG is supplied with extra sets of ars so that it may operate at speeds of 368 p.m. (60 w.p.m.), 404 o.p.m. (66 w.p.m.), 50 o.p.m. (75 w.p.m.) and 600 o.p.m. (100 .p.m.).

Test Set TS-2/TG is 23" × 17" × 14" and eighs 70 pounds. The test set is mounted on base casting which is attached to a rein-orced wooden base. A strongly reinforced ooden cover with two carrying handles houses he test set and fastens to the wooden base ith four trunk-type latches. One half of the op of the wooden cover consists of a hinged d. When this lid is open, it exposes the con-ol panel, which is equipped with control witches and local test jacks, and permits the est set to be operated without removing the ooden cover from the wooden base.

The control switches and jacks, with the ex-eption of the target light and the radio filter ut-out switches, are mounted on the control anel which is located above the motor. A mall door on the control panel permits access o the target light switch. The radio filter cut-ut switch is mounted in the base casting of he test set.

The motor is an alternating current governed series motor which may be adjusted for use at 368.2 or 404 o.p.m.

A small wooden box containing a spare target light, two spare fuses, sandpaper, two small brushes, and two large brushes, is mounted on the wooden base at the motor end of the test set.

The several models of the test sets vary slightly in external appearance. The later models have been modified to improve operational features.

Distributor

The distributor face is equipped with four concentric rings. The two outer rings are segmented and the two inner rings are solid conductors. The outer segmented ring is movable so that it can be adjusted, with respect to the inner segmented ring, to send any amount of distortion from 0 to 50 per cent. The amount of distortion is indicated on a scale at the side of the distributor disk. (See fig. 12.9).

Attached to the main shaft assembly is a brush holder assembly (fig. 12.3). The brush holder assembly mounts two sets of brushes which are drawn, in a clockwise direction, across the concentric distributor rings. One pair of brushes makes contact with the outer (movable) segmented ring and the outer solid ring. When undistorted signals are transmitted, these brushes are the only ones involved. The other pair of brushes makes contact with the inner segmented ring and the inner solid ring. Both sets of brushes and rings are used to

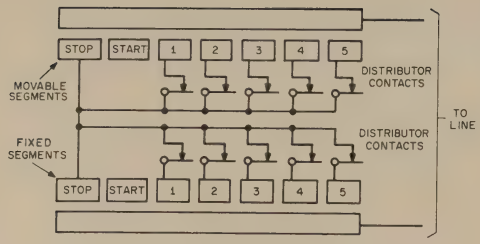


Fig. 12-5 - Connections for spacing bias.

transmit distorted signals by connecting the corresponding segments of the movable ring and the stationary ring electrically, either in series or in parallel.

The distributor rings are electrically connected, through the transmitting contacts and the character selecting switch, to the signal line. This provides a means of transmitting the signals at the correct speed and sequence to the equipment under test.

The segmented rings correspond to the impulses of the teletypewriter code; that is, a start segment for the start impulse, five code segments for the intelligence impulses, and a stop segment for the stop impulse. The distributor brushes make one complete revolution to transmit the code combination for each character or function. When a brush passes over the start segment, a spacing impulse is always transmitted. When a brush passes over the stop segment, a marking impulse is always transmitted. These two impulses keep the distributor and the receiving teletypewriter equipment in step or synchronism.

Distortion is introduced into the signal by positioning the outer movable segmented ring and by connecting these rings in either series or parallel by means of the distortion switch before completion of the electrical path to the signal line.

Character Selecting Switch

The character selecting switch is a 6-pole, 5-position switch. The positions are: R, Y, TEST MSG, RPT SP, and STOP. In the TEST MSG position, the character selecting switch connects the code disk transmitter to the signal line. In the R, Y, and RPT SP positions, the switch disconnects the code disk transmitter

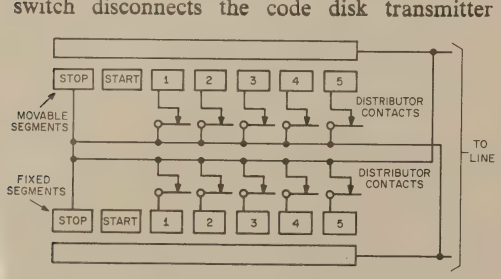


Fig. 12.6 - Connections for marking bias.

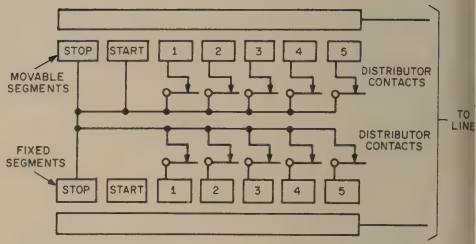


Fig. 12.7 - Connections for spacing end distortion.

from the signal line and connects the distributor rings in the correct sequence to the signal line. With the switch in the R position, segments 2, 4, and the stop segment are connected to the signal line. With the switch on Y, segments 1, 3, 5, and the stop segment are used. The switch, in any of the above positions, permits a continuous selected function to be transmitted. When the character selecting switch is in the STOP position, the signal line is shorted, preventing any signals from being transmitted but providing a closed circuit to the equipment under test.

Distortion Switch

The DISTORTION switch is a system of make-break spring contacts which are ganged together and operated by a bakelite camshaft. The switch may be set for ZERO distortion, BIAS M, BIAS S, ED M, and ED S. The selections are defined by a detent roller and lever which presses against a detent cam mounted on the lower end of the bakelite camshaft.

When bias is provided by the test set, all *space*-to-*mark* transitions are advanced or retarded with regard to the beginning of the start impulse of a teletypewriter character. *End distortion* differs in that all *mark*-to-*space* transitions are advanced or retarded with regard to the beginning of the start impulse. Figure 12.4 shows examples of distorted signals.

When spacing bias is desired, the segments of the segmented commutator rings are connected in series as shown in fig. 12.5 by setting the DISTORTION switch to BIAS S. The segments are connected in series; therefore, current will flow through the selected segments of the two rings only during the time these segments overlap. The beginning of the *mark* impulse is re-

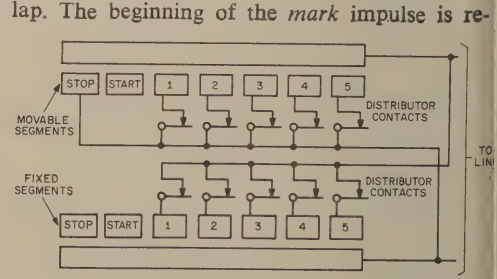


Fig. 12.8 - Connections for marking end distortion.

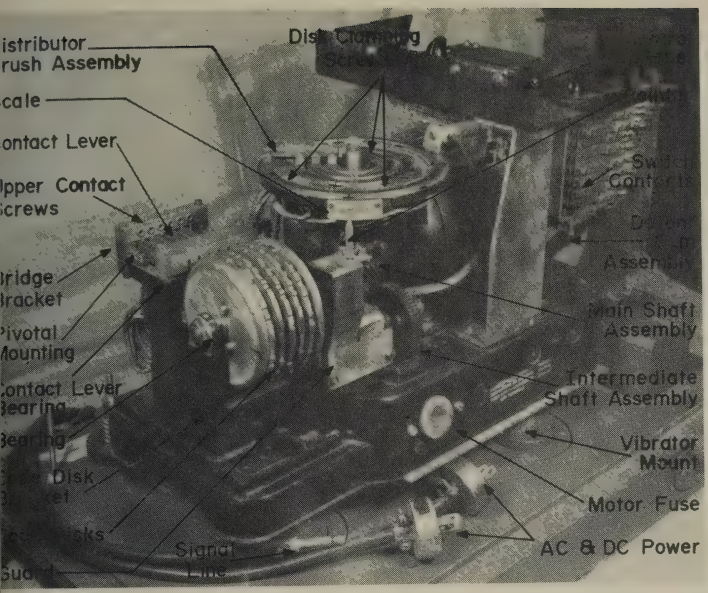


Fig. 12.9 - General view of test set TS-2/TG showing code discs, distributor and drive gears.

arded as shown in (a) of fig. 12.4.

When marking bias is desired, the segments f the commutator rings are connected in arallel as shown in fig. 12.6 by turning the ISTORTION switch to BIAS M. Since the segments re connected in parallel, current flows as llustrated in (b) fig. 12.4. This shows the beinning of the *mark* impulse advanced with egard to the start impulse.

When spacing end distortion is desired, the egments are connected as shown in fig. 12.7 y setting the distortion switch to ED S. Since he segments are again connected in series, urrent flows when the selected segments overap, with the result shown in (c) of fig. 12.4. The end of the *mark* impulse is advanced. Note that the start and stop segments of the novable segmented ring are connected, resulting in a start impulse always equal to a unit ength impulse.

When marking end distortion is desired, the egments are connected as shown in fig. 12.8 y setting the distortion switch to ED M. Note hat in this case, only one movable stop segment is used and that the several selecting segments are connected in parallel. The resultant current flow is shown in (d) of fig. 12.4. The end of the marking impulse is delayed.

Signal traces (a), (b), (c), and (d) in fig. 12.4 have been redrawn and are shown as traces (e), (f), (g), and (h). The latter four traces are identical with the former except that the beginning of the start impulses are brought into line with each other to illustrate the manner in which the signals appear to a start-stop receiving selector mechanism.

Unbiased signals are obtained from the fixed segmented ring and its associated continuous ring by setting the distortion switch to ZERO. The resultant current impulse is shown in (i) of fig. 12.4.

Code Disk Transmitter Assembly

The code disk transmitter assembly (figs. 12.9 and 12.10) consists of five code disks, five contact levers, five contact tongues, and ten contacts. The code disks are driven by an intermediate shaft assembly which, in turn, is driven by the main shaft through a gear arrangement.

The five contact levers pivot about a shaft in the contact lever bearing. At the outer end of the contact levers are pivotal mountings. Attached to these mountings, but insulated from them by fiber insulators, are contact tongues which ride between the upper (spacing) and lower (marking) contacts. Springs are connected between the contact tongues and a terminal block. These springs serve a dual purpose. They hold the contact tongues on the lower contacts until the tongues are forced up by the code disks, and they afford an electrical connection between the terminal block and the contact tongues. Thus, when the tongues are in the lower position, an electrical connection exists from the terminal block, through the contact tongues, and through the lower contacts to the character selecting switch.

The five code disks contain cams of various lengths spaced around their outer rims. The disks are bolted together and rotate with a fixed relationship to the rotation of the distributor brush arm. A friction assembly, located at the end of the code disk cam assembly,

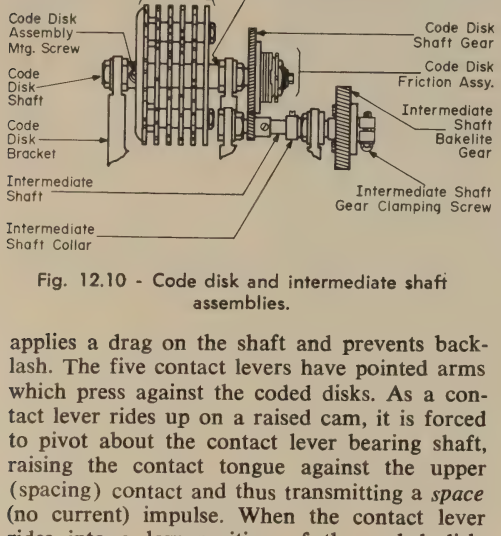


Fig. 12.10 - Code disk and intermediate shaft assemblies.

applies a drag on the shaft and prevents backlash. The five contact levers have pointed arms which press against the coded disks. As a contact lever rides up on a raised cam, it is forced to pivot about the contact lever bearing shaft, raising the contact tongue against the upper (spacing) contact and thus transmitting a *space* (no current) impulse. When the contact lever rides into a low position of the coded disk, the contact tongue is pulled down to the lower (marking) contact, transmitting a *mark* (current) impulse. The coded disks are so arranged that at any one position, the five contact levers hold the contact tongues in the positions necessary to transmit marking and spacing impulses in the correct sequence to form a complete character or function in accordance with the teletypewriter 5-unit start-stop code. One complete revolution of the code disks on Test Sets TS 2/TG and TS-2A/TG transmits the test message THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING, followed by one carriage return and two line feed combinations. One complete revolution of the code disks on Test Sets TS-2B/TG transmits the same test message followed by four letter combinations, two carriage return combinations, one line feed combination and one letter combination.

The electrical circuit from the distributor through the transmitting contacts to the signal line is completed by setting the character selecting switch in the TEST MSG position. When the character selecting switch is in any other position, the transmitting contacts are open and the test message is not transmitted to the signal line.

Distortion Test Set TS-383/GG

Distortion Test Set TS-383/GG is a portable, motor-driven teletypewriter signal distortion test set made by Teletype. Prior to the assignment of official nomenclature this test set was referred to in other technical manuals by the manufacturer's designation, distortion test s DXD1 or DXD4.

The test set is designed to transmit eith perfect or biased five-unit start-stop teletyp writer signals for testing and calibrating pu poses. It is equipped with a neon strobosco indicating lamp. The test set shows accurate the length of the seven impulses making up t five-unit start-stop signals received from a tel typewriter circuit or equipment under test. Di tortion produced in the transmitted signals ma be either marking or spacing bias or markin or spacing end distortion. Transmitted signa are a continuous repetition of one of the follo ing 10 choices: a standard test message, R, T, O, M, V, LET (letters), BLK (blank), or cod length marking impulses. The selected test si nal can have a controlled amount of distortio from zero to approximately 100 percent.

The test set may be equipped with a 110- 115-volt, 60-cycle synchronous motor uni which includes gears for 368.1 o.p.m., or 110-to 115-volt, 60-cycle governed motor uni A governed motor requires greater care than synchronous motor for accurate results. A go erned motor must be used, however, when tes ing British (Creed) equipment.

To get accurate stroboscope readings, the te set and the equipment being tested must b connected to the same source of power. Th 110 to 115-volt d.c. required for the signal lin must be supplied from an outside source, no mally the equipment being tested.

Physical Description

Distortion Test Set TS-383/GG is a self contained unit 19" long, 13½" high and 14 deep and weighs 125 pounds. The test set mounted on a single base, on the under part o which are the terminal blocks and filters. A of the controls are available on the front panel of the test set.

A large circular panel is mounted on th front of the test set. The circumference of thi panel is scaled off in seven divisions, compar able to the five-unit start-stop teletypewrite code. A removable face plate covers the dis tributor face which is equipped with six con centric rings. The two outer rings, one movabl and the other stationary, are segmented ring and the four inner rings are solid conductor A hub, which revolves around a main shaf mounts the distributor brush arm and the lam arm. Six brushes, one for each distributor rin are mounted on the brush arm. A small neo lamp, which provides a visual stroboscop measurement of the various functions of th test set, is mounted on an arm opposite th brush arm.

A metal cover, housing the interior of th test set, is held in place by three screws. Acces to the interior of the test set may be had b

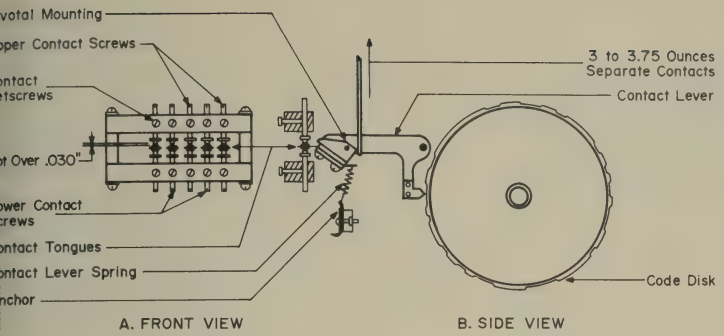


Fig. 12.11 - Contact lever and contact bracket assembly.

moving these screws, one in the rear of the ver and one on either side. Removing the ver exposes the motor unit, code disk trans- itter, and gear assemblies.

At the rear of the test set are five cords for aking the various connections. A rubber-cov- ed cord with a convenience plug is provided r connection to an a.c. power source. Two ate-colored cords with black and red plugs are ovided for connection to —110 and +110 lts d.c. Two green cords with black and red ugs are provided for incoming and outgoing gnals.

A cylindrical metal hood, which slips over e circular front panel, provides a light shield facilitate easier and more accurate reading the stroboscope indicating light.

Differences In Models

Late DXD1 models and all DXD4 models of istortion Test Set TS-383/GG have a toggle vitch, STOP PULSE, on the right-hand control anel for disconnecting the stop pulse. This ermits transmitting a single marking impulse f code length with the code selecting switch t to T. Early models of the test set are not quipped with this toggle switch.

All DXD1 models of Distortion Test Set S-383/GG have one cord for providing d.c. ower for the stroboscope. DXD4 models are quipped with two single-conductor cords, one ith a red plug for negative 115 volts d.c. and ne with a black plug for positive 115 volts d.c.

On the main shaft, the gear used in early DXD1 models of Distortion Test Set TS-383/ GG has been replaced in late DXD1 and DXD4 models with a 44T gear if the unit is quipped with a synchronous motor or a 40T ear if the unit is equipped with a governed notor. The hub used with either of these gears s tapered, and tightens onto the shaft as it is crewed into the gear.

A reverse rotation stop, mounted on the main haft at the rear of the frame, has been added n late DXD1 and in DXD4 models of Distor- ion Test Set TS-383/GG. This stop prevents a counterclockwise rotation of the brush arm.

Late DXD1 models of Distortion Test Set TS-383/GG have a brake which bears against the outer ring on its upper left-hand corner. This brake prevents rotation of the ring after it has been set in a desired position.

A 250,000 ohm resistor has been added across the contact springs of the LINE DIST key on late DXD1 models and on DXD4 models.

A cylindrical hood is supplied with DXD4 models of the distortion test set to improve the visibility of the signals. The hood fits over the movable ring behind the distortion measuring scale.

A brake has been added to late DXD1 models of Distortion Test Set TS-383/GG to prevent rotation of the distortion control after it has been set in a desired position.

Application

The principal uses of Distortion Test Set TS-383/GG are: (1) Checking the efficiency of the selecting mechanisms in teletypewriters and reperforators. (2) Checking the operation of relays used in terminal, switching, or repeater equipment. (3) Measuring the length of each of the seven impulses transmitted by a teletypewriter, transmitter distributor, or reperforator to determine the amount (percent) of distortion in the signals. (4) Measuring the amount (percent) of distortion in the signals received from a distant teletypewriter or transmitter connected either by wire or radio circuits. (5) Calibration of bias meters in Switchboard BD-100 and Line Unit BE-77.

The Distortion Test Set TS-383/GG is designed and built to conform with the normal American speed of 368.1 o.p.m. with a 7.42-unit code length. The British code length is 7.50, operating at a speed of 400 o.p.m. When operating American teletypewriters with British equipment the American equipment must transmit its 7.42 unit code lengths at an increased speed of 404 o.p.m. The same precautions as to length of typed lines and various operational features that pertain to inter-operation of teletypewriters should be observed when using this

Fig. 12.12 - Wang Laboratory Teletypewriter Signal Generator test set AN/UGM-5.

test set. Special adjustments must be made whenever testing any equipment which transmits other than a 7.42 unit code length (old style 7-unit characters).

Test Set AN/UGM-5

The AN/UGM-5 Teletypewriter Test Set shown in fig. 12.12 is currently being manufactured by Wang Laboratories, Inc. of Tewksbury, Massachusetts. As one would imagine, from the type number, it is manufactured for the U.S. Armed Services. The company manufactures a commercial version, which is the Model 2069A. This unit has the added feature of being able to stop on a character, and also to transmit single characters. The Test Set AN/UGM-5 consists of Test Set TS-1908/UG and Carrying Case CY-3914/UGM-5.

The AN/UGM-5 is a portable, self-contained dual output message generator for testing start-stop teletypewriter receivers. The unit is completely solid state and transmits programmed words and letters for teletypewriter receiver testing. The signals provided by the test set may be clear or distorted.

The test set is designed to test both domestic and foreign made teletypewriter receivers by providing an eighty character fixed message as a reference. It operates internally at speeds of 45.45, 50.0, 56.8, and 75.0 baud. This corresponds to 60, 66, 75 and 100 words per minute. In addition, it may receive an external oscillator with speeds up to 1200 baud. Speed in baud is equal to the number of *mark* and *space* or on and off code elements per second.

The TS-1908/UG will supply a fixed eighty character message, alternating selected characters, and dot (unit length) cycles or reversals. These messages may be supplied in 7.0, 7.5, or 8.0 unit intervals per character.

The test set has dual electronic outputs. One output is constantly undistorted while the other has controlled telegraph distortion from 0 to 49 percent in 1 percent increments. Distortion may be supplied in the form of marking bias, spacing bias, switched (switching from *mark* to *space*) bias, marking end, spacing end, switched end, or a sequential (marking bias to spacing bias, to marking end to spacing end every four characters) type of distortion.

A standard teletypewriter signal may be s
lected and generated with a stop bit 1.0, 1.
or 2.0 units long and a nominal speed of
baud.

Functional Operation

Teletypewriter Signal Generator Test Set T
1908/UG is designed to operate at any one
four internal frequencies or an external fr
quency of 2400 kc. A selected frequency the
passes through a series of five counters in ord
to reduce its frequency to a desired rate
which point two additional counters genera
eighty independent timing signals which co
trol any one of thirty-two characters in a fi
bit teletype code. This thirty-two charact
fixed message may then be undistorted or di
torted at any 1 percent integer between 1 ar
49 percent. In addition to the fixed messa
any alternating repeated character message ma
be selected by means of ten switches locate
on the front panel. This alternating charact
message bypasses the eighty character matr
and the two five-bit teletype codes may be di
torted or undistorted. Dot cycles or signal r
versal are also provided.

Summary

Several telephone men, who earn their livel
hood servicing teletype equipment, have sa
that they concern themselves more with bi
distortion than with end distortion. They test
teletypewriter by feeding a signal with bias
end distortion from a test set into the teletyp
writer under test. They usually consider th
when they get the machine to function witho
errors on a signal with up to 40% marking bi
distortion present, it is in pretty good conditio
and that they may not always feed addition
distorted signals into the machine for furth
tests.

The first thing to do on a machine is to s
the range finder spread on a standard Fox se
tence test. One teletype service man (who
also a ham) stated that he never tests the m
chines on *mark* and *space* end distortion. H
uses marking and spacing bias tests only. H
sets the distortion producing test set on 40
marking bias and then on 40% spacing bia
If the machine can copy under these condition
then, he says, that the machine is in real goo
condition. He further stated that if he took 1
average amateur machines and checked the
that probably 80% would not pass this test.

Usually, but not always, the selector magn
has bias which is the cause of not passing th
above test. Marking bias indicates a weak a
mature spring and if the armature spring
is too strong you will have spacing bias. Th
spring has to be readjusted accordingly.

13

REGENERATIVE REPEATERS AND FREQUENCY SHIFT MONITOR

It has already been pointed out that a teletypewriter such as the Model 15 is designed so that it functions in about four or five milliseconds of time which is a relatively small portion of the signal pulse length (22 ms for a speed of 60 w.p.m.). Stating it another way, it may be said that the machine samples 4 to 5 ms of the pulse and in a properly adjusted machine, this sample should occur at the center of the 22 ms pulse. Bias or end distortion affecting the front or end of a pulse has no effect on the operation of the machine so long as these discrepancies do not extend into that portion of the pulse where the sampling takes place.

It may be seen, then, that the teletypewriter itself can be used to restore a signal whose timing has been upset by bias or end distortion. A device that performs this function, the restoration of timing, is called a regenerative repeater. It repeats the signal and regenerates the proper timing while doing so.

Based on the condition and adjustment of a machine there is a good chance that the sampling will not occur at the center portion of the pulse. This then cuts down the maximum percentage of distortion that the machine can tolerate before errors occur. From a practical standpoint the characteristics of the machine as a regenerative repeater may not be as attractive as one might first think.

It might be possible to devise an electronic circuit that would always sample the center portion of the pulse, or any other portion, at the turn of a knob. It could have an added advantage if it operated on a sample even shorter than the 4-5 ms required by a teletypewriter such as the Model 15. Under these conditions the maximum allowable bias or end distortion for which the device was designed could be maintained at all times and it would certainly outperform the teletype machine as a regenerative repeater. Such a device would be a nice companion for the Model 14, 15 or other similar machines and one was built for the Navy and is available on the surplus market at a nominal price. The device is called a Teletypewriter Repeater TT-63A/FGC and is part of Teletypewriter Repeater Set AN/FGC-7A which contains eight such repeaters.

It is not considered necessary to go into the details of the generation, transmission and reception of the on-off type *mark* and *space* signals since this has been covered elsewhere in the text. At this point, we are focusing our attention on the teletype signals as they appear

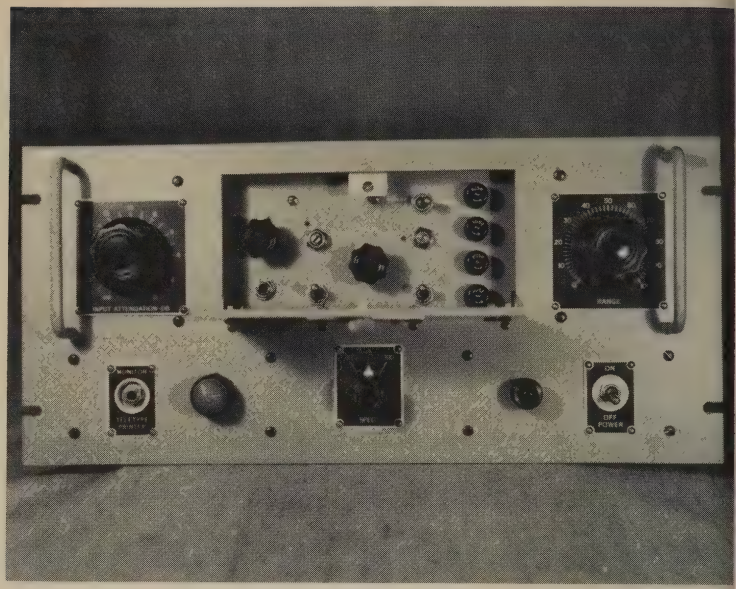


Fig. 13.1—Front view of the Navy surplus TT-63A /FGC Teletypewriter Repeater. The front panel "window-door" is open, showing fuses and a number of additional controls.

at the audio output of a radio receiver. Several things can happen to the signal at this point, depending upon the operator's equipment.

The signal may feed into a repeater or into a device called any one of *several names* such as converter, terminal unit or even a "receiver." The device may be relatively simple or it may be a number of things all in one including a repeater. In many such devices, excluding the repeater, the signal passes through a limiter which restores the square form of the signal. This is helpful but it does not go far enough. There may still be *timing* displacements due to transmission impairments of one kind or another.

It is seen that one must go one step further. One must also restore the original timing of the wave of the signal. Such a device that does this is called *regenerative repeater.*

Regenerative Repeater

Basically, the regenerative repeater samples the received wave near the center of each pulse. These binary samples of the received wave are used to regenerate a new wave that is more properly timed. The improper or defective received wave is discarded and replaced by one that is more nearly a replica of the transmitted wave. Naturally, the timing of the regenerated wave must be synchronous with the incoming signal wave which can be derived from the long time average of the incoming *signal wave transitions* in some instances. How the repeater does all of this will be covered in a moment.

Distortion Tolerances

The theoretical maximum distortion tolerance of such a system can be considered to be near ± 50 percent. This would involve perfect pulses (undistorted), perfect timing and the samples taken at the exact centers of the pulses. Under such circumstances, you would not need a repeater anyway. The realistic maximum distortion tolerance of a regenerative repeater is more like ± 45 percent. The signal that the radio amateur is familiar with in RTTY work uses a start-stop system of synchronization. In such a system, the sampling of the wave is phased with a *particular signal transition* in each transmitted *character* and not with each pulse as indicated above. This reference can deteriorate during the course of the progressive transmission of each character.

It must be assumed that the reference transition is subject to the same distorting effects as the other transitions in the character. Under these considerations errors can occur when the distortion reaches ± 25 percent considering a fixed time scale. A more realistic figure would be ± 20 percent in order to avoid errors.

TT-63A/FGC Repeater

Teletypewriter Repeater TT-63A/FGC (hereafter referred to as Repeater) is capable of accepting teletypewriter signals in audio (on/off) form or in direct current form (polar and neutral) having up to 45% bias distortion and regenerating the signal to have less than 5% bias distortion at the output.

Regeneration of the teletype signal in the Repeater is accomplished by electronic means. Sampling pulses are generated in the Repeater to synchronize with the center of each teletype pulse. If a sampling pulse coincides with a

mark, the pulse operates a relay circuit to produce a regenerated *mark* at the repeater output. If the sampling pulse coincides with a *space*, the relay circuit will produce a *space* of proper duration at the Repeater output.

The Teletypewriter Repeater TT-63A/FGC is illustrated in fig. 13.1. The panel is 19" long by 8¾" high, and the chassis extends 10½" behind the panel. The controls most often used are located on the Repeater panel. Seldom used controls and fuses are located behind the access door in the center of the panel. Input, output, and power connections are located at the rear of the chassis. All vacuum tubes and relays are readily accessible from the rear and are mounted in a vertical position. The Repeater normally functions as an individual unit in the Teletypewriter Repeater Set AN/FGC-7A. On Diplex reception the input of two Repeaters are connected in parallel and the outputs operate two teletypewriters. A separate power supply to operate the teletypewriter printer is required as the output of the Repeater is in the form of relay contacts.

Reference Data—TT-63A/FGC

Input: 60, 75, or 100 w.p.m. teletype signals.

Input keying: Tone - 500 to 3,600 c.p.s., 30 ma polar, 60 ma neutral, simplex or diplex; d.c. keying must be negative with respect to ground on *mark*, tone keying may be either normal or inverse.

Output: Relay contacts in series with a 310 ohm resistor. Either *mark* Hold or Normal output operation available.

Acceptable input distortion: 45% *mark* or *space* bias.

Output distortion: less than 5%.

Tone input level: −20 dbm to 0 dbm.

Power requirements: 105 to 125 v., 50 to 60 c.p.s., 85 watts per Repeater.

Visual operation indicator: Neon lamp on front panel.

Power Supply: Built in on each Repeater.

Monitor Teletypewriter: Front panel jack for monitor teletypewriter.

A general top view of the chassis is shown in fig. 13.2. The connecting terminal strip may be seen at the rear left of the picture. The gate controls for 60 w.p.m., 75 w.p.m. and 100 w.p.m. and RANGE control are in the small compartment mounted on the rear of the upper portion of the front panel. These are screwdriver slot controls.

Block Diagram Of TT-63A/FGC Circuit

Figure 13.3 illustrates a block diagram of the Repeater showing routing of signal from input to output. The wave shapes of the signal at pertinent points of the circuit (indicated by letters *A* to *M*) are shown in fig. 13.4. The time

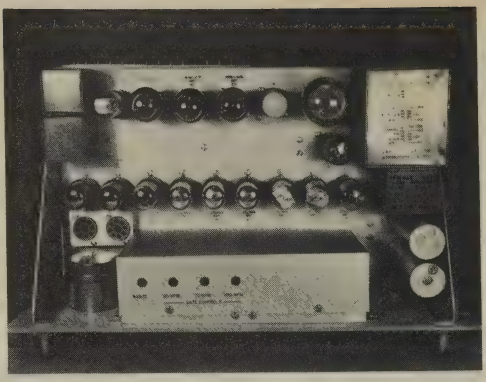


Fig. 13.2—Top view of the chassis of the Navy surplus TT-63A/FGC Teletypewriter Repeater.

base is for 60 w.p.m. operation, but similar circuit function occurs at 75 and 100 w.p.m. so these time bases are not shown. A speed switch not shown on the block diagram changes timing in tubes V_5, V_6, *and* V_7 to permit circuit operations to synchronize with either 60, 75, or 100 w.p.m. operation.

It will be assumed that a keyed tone teletype signal is applied to the input of the Repeater. A signal for the character Y is illustrated in fig. 13.4 where the tone is on for the stop *mark* and off for the start *space*. The tone signal is amplified by triode V_{1A}, limited by dual diode V_2 to allow operation on varying line levels, and again amplified by triode V_{1B}. This signal (point *B* fig. 13.3 and line *B*, fig. 13.4) is then applied to a full wave rectifier tube V_3, the output of which is illustrated in line *C*. The curve on the rise and decay time of voltage is due to filtering after the rectifier. The output of V_3 is applied to trigger tube V_4 as is the d.c. input voltage when polar or neutral d.c. keying is applied to the Repeater, instead of tone keying.

Trigger tube V_4 performs the function of giving a square wave positive voltage output. (See line *D*.) Output from V_4 is applied to V_{8A} V_{8B}, and V_{9A}. Output from V_4 is also differentiated and the resultant positive pulse (line *E*) is used to trigger the one shot multivibrator lag tube V_5. The operating time of this tube (point *F*, fig. 13.3 and line *F*, fig. 13.4) is adjustable by means of the RANGE control and is normally set for 11 ms on 60 w.p.m. teletype so that the tube will trigger off at the time center of the start space. Output from V_5 is differentiated at point *G* (see line *G*) and the resultant positive pulse is applied to the False Start Gate tube, V_{8A}. This triode tube is gated by the Trigger Signal so that if the differentiated pulse from V_5 coincides in time with the Trigger signal, the pulse will appear at output of V_{8A} and operate Gate Tube V_6.

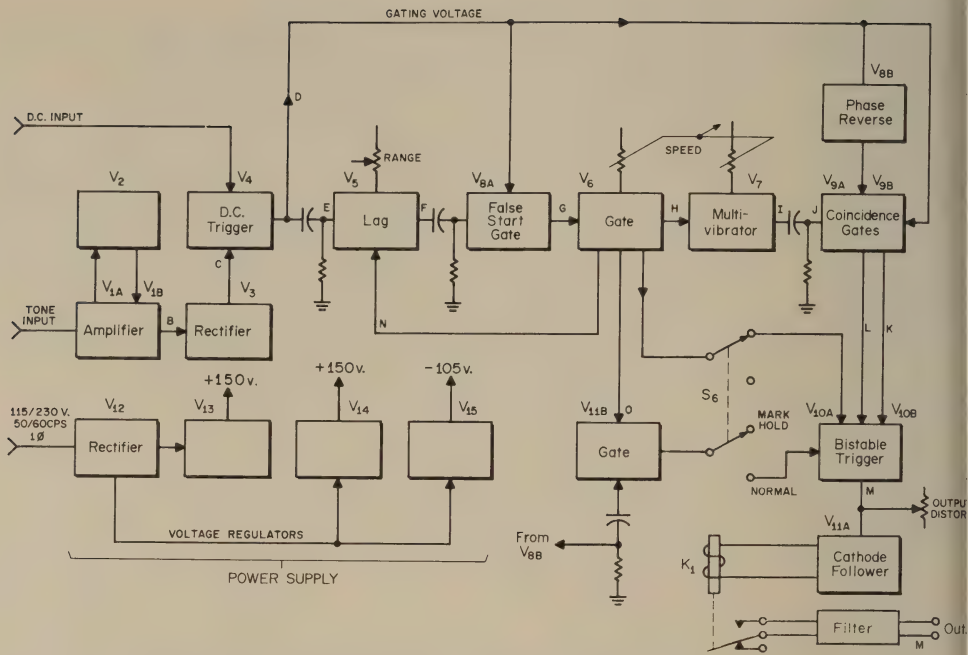


Fig. 13.3—Block diagram of TT-63A/FGC Teletypewriter Repeater. See text for discussion.

If the differentiated pulse from V_5 does not coincide with a Trigger signal, no pulse will appear at the output of V_{8A}. Assuming a start pulse of 8 ms length due to noise or some other random condition, the pulse from V_5 will occur 11 ms after the start of the 8 ms trigger signal, will not coincide with the Trigger signal and no pulse will occur at the output of V_{8A}. Under normal conditions the pulse applied to the input of V_{8A} will appear at its output and the one shot multivibrator gate tube, V_6 will be triggered to its operating condition.

Tube V_6 remains in its operating condition for 143 ms (line *H*) during which time it performs two operations: (1) Lag tube V_5 is biased off (connection *N* in fig. 13.3) so that additional pulses after the start pulse will not trigger this tube, (2) Multivibrator tube V_7 is turned on for 6½ cycles of operation and then off. See line *I*. The multivibrator output is differentiated to produce a positive sampling pulse for each of the six 22 ms teletype pulses and for the stop mark. See line *J*. These sampling pulses are about 1 ms wide. A SPEED control consisting of a ganged variable resistor permits adjustments of the multivibrator frequency so that a sampling pulse occurs exactly at the center of each teletype pulse.

The sampling pulses are applied to both sections of coincidence gate tube V_9 which operates in similar fashion to False Start Gate tube V_{8A}. A gating voltage is also fed to th coincidence tube V_{9A} from the trigger tub output. A gating voltage 180° out of phas with the trigger voltage is fed to tube V_{9} Tube V_{8B} is used to secure the phase reversa The first, third, and fifth sampling pulses ap plied to V_{9A} will coincide with a positive gat ing voltage to that tube and will appear at th output of tube V_{9A} to drive tube V_{10A} (Se line *K*). The second, fourth, sixth and seventi sampling pulses applied to tube V_{9B} will coin cide with a positive gating voltage to that tub and will be applied to tube V_{10B}. (See line *L*)

Tube V_{10} is a bistable multivibrator trigge tube which triggers to one stable state when pulse is applied to the *A* section. When a puls is applied to the *B* section, it triggers back t the original state. Output from tube V_{10} i shown in line M. This is an undistorted replic of the input signal. Cathode follower tub V_{11A} is used to drive the relay K_1 and i driven by the output from tube V_{10A}. The in put impedance of V_{11A} is high and does no load tube V_{10}. A potentiometer in the gri circuit of V_{11A} regulates the relay current an provides the output DISTORTION control. Rela output will also look like line *M*.

Two types of output operation are possibl from the Repeater. For MARK HOLD opera tion switch S_{6A} applies a pulse from Gate tub V_6 to trigger the Bistable Trigger tube V_{10} to *mark* at the end of each gate cycle. Thus

e output will return to *mark* even when the put goes from *mark* to steady state *space*. or NORMAL output (output follows steady put state) a transition from *mark* to *space* ll allow the last multivibrator sampling pulse sample *space* and leave the output on *space*. n a *space* to *mark* transition sampling pulses e not generated. The transition pulse is there- re applied from tube V_{8B} through an *RC* fferentiating circuit to Gate tube V_{11B} and en through switch S_{6B} to Bistable Trigger be V_{10B} to trigger the output to *mark*. When e Repeater is in operation with a message, e Gate tube V_6 keeps tube V_{11B} disabled oint O, fig. 13.3) during all *space* to *mark* ansitions. Signals then applied to tube V_{11B} om tube V_{8B} do not appear at the output of $_{11R}$.

During operation with the sampling pulse at e center of each 22 ms teletype pulse and out 1 ms wide, it is possible for the input gnal to have *mark* bias distortion extending) ms into the *space* signals and still have the mpling pulse sample correctly. Output from e Repeater will be correct and undistorted long as sampling is correct. Similarly, *space* as distortion may extend 10 ms into the *mark* gnals without faulty operation. Thus 45% bias stortion may be tolerated by the Repeater ithout producing faulty output. Speed adjust- ent of the Repeater must, of course, be per- ct to secure operation at 45% bias distortions.

Operation

The Teletype Repeater TT-63A/FGC should ldom require attention from the operator ter the equipment is installed, checked, and

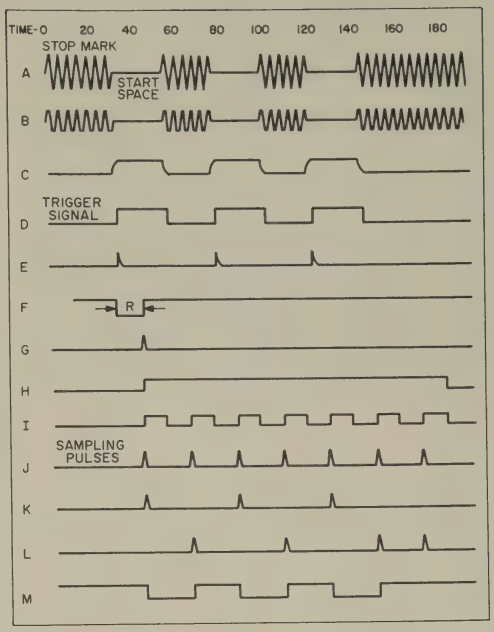


Fig. 13.4—Functional waveforms of TT-63A/FGC Teletypewriter Repeater.

adjusted. While the adjustments of the Repeater are very important to secure optimum performance, it should not be necessary for the operator to readjust the equipment unless another type of signal input is connected to the Repeater, or unless the speed or amplitude of the input signal changes.

The Repeater is specifically designed to correct for bias distortions in teletype signals and

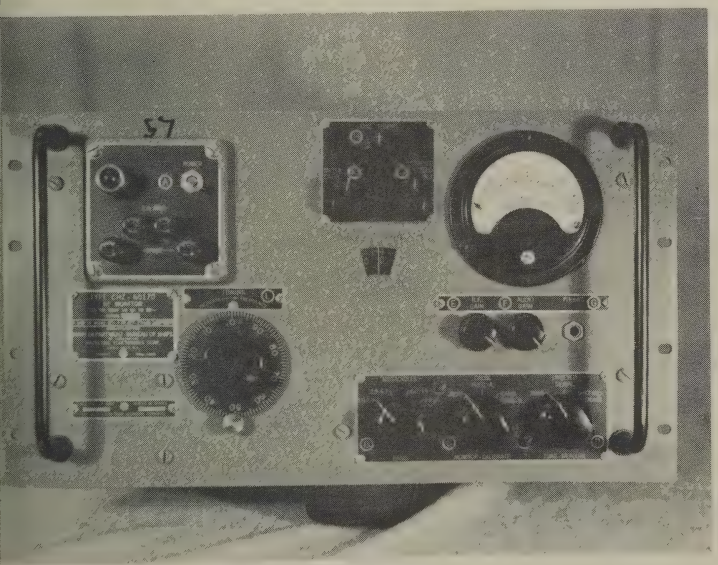


Fig. 13.5—Front view of Navy OCT-3 Frequency Shift Monitor.

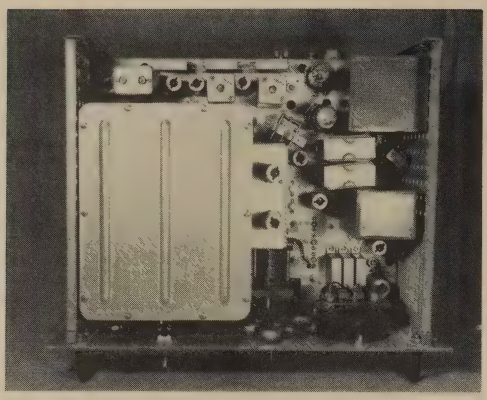


Fig. 13.6—Top view of Navy OCT-3 Frequency Shift Monitor.

when properly adjusted, *mark* or *space* bias distortions of 45% are corrected to less than 5% at the Repeater output. There are conditions which will cause faulty operation of the Repeater. These conditions are most often found in signals from radio circuits.

If there is a missing start pulse due to a fading signal, the Repeater will be started by a following intelligence pulse and will print errors for a few characters until the Repeater corrects itself.

If the start pulse is too short in duration (less than 10 ms for 60 w.p.m. operation), it will be treated as noise and intercepted by the Repeater so that a following intelligence pulse longer than 10 ms will act as the start pulse and errors will be printed for a few characters.

If there is a missing intelligence pulse or if there is a split or knock-out in one of the intelligence pulses at the point sampling occurs, an error will be printed.

If the speed of the incoming signal changes, the amount of bias distortion that can be accepted by the Repeater will be reduced. Since the change in speed would appear as an increase in distortion, periodic speed checks should be made on the Repeater. Actually the unit may be used as a very satisfactory means of copying other than the 60 w.p.m., 75 w.p.m. and 100 w.p.m. as provided for in the unit. The unit may be used as a means of copying the European standard speed of 67 w.p.m. on a 60 w.p.m. teletype machine. The speed error is treated as bias and is eliminated. This is done by advancing the front panel RANGE control to about ten. This scale is calibrated from zero to one hundred and is the upper right hand control shown in fig. 13.1.

The Repeater is intended to perform two general functions. The first is to regenerate single channel teletype signals before operating a teletype printer. The second is to regenerate diplex teletype signals to single channel form for the operation of a teletype printer.

Frequency Shift Monitoring

Originally most RTTY'ers used a frequency shift of 850 c.p.s. This made it fairly easy to line up the transmitter on the proper shift since everyone used the same shift, more or less. Terminal Unit filters were usually fairly broad so it did not matter too much if one did not hit it right on the nose anyway. All of this is changed now. Filters are sharper and a variety of shifts are used. Some of the more sophisticated terminal units in use are capable of copying any frequency shift from about 70 c.p.s. to 900 c.p.s. Unfortunately, such TU's are in the minority.

In view of the above, a device to readily measure and monitor transmitted frequency shift would be most helpful. Imagine being able to say to the other fellow, "Let's try a shift of 510 c.p.s. or 170 c.p.s.," and then moving right on the proper frequency shift. Fortunately, there is such a device and it is available on the surplus market at a nominal sum. The device was manufactured for the U.S. Navy in Models OCT-2 and OCT-3. These models are identical electrically. The differences are in mounting and dimensions.

Navy F.S. Monitor

The Frequency Shift Monitor Equipment, Navy Models OCT-2 and OCT-3 are test equipments designed for use in measuring carrier-frequency shift of transmitters used in the frequency-shift telegraph system over the range of one to 26 megacycles. The equipment measures the total frequency-shift from *space* to *mark* over the limits of zero to 1500 c.p.s., and functions on keyed or unkeyed signals. Since it is not necessary to interrupt periods of traffic to manually measure the amount of frequency-shift being used at the transmitter by keying first to the space frequency and then to the mark frequency, the equipment may be used as a continuous frequency-shift monitor.

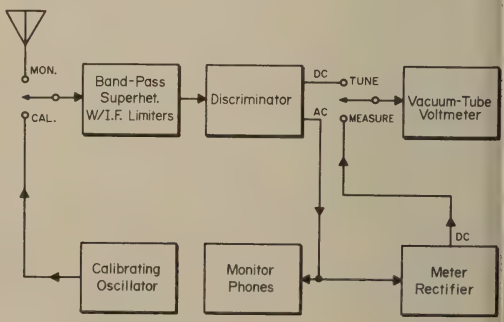


Fig. 13.7—Basic block diagram of Navy OCT Frequency Shift Monitor.

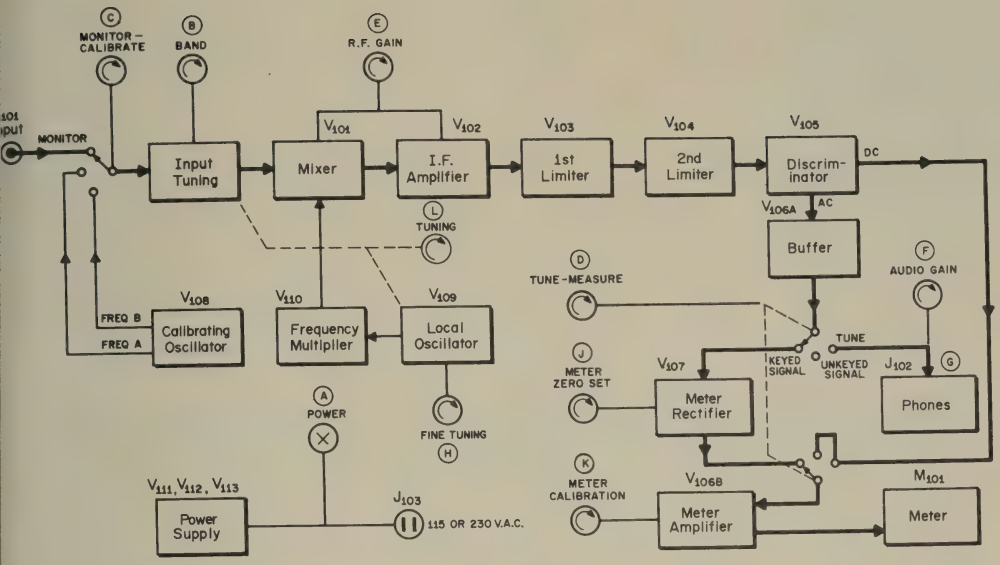


Fig. 13.8—Detailed block diagram of Navy OCT Frequency Shift Monitor.

Frequency Shift Monitor OCT-2 is intended for shipboard use and is supplied in a shock-mounted cabinet, while the OCT-3 is designed for rack-and-panel mounting in shore-type installations. The R.F. Monitor, comprised of the panel and chassis is the major unit of both the OCT-2 and OCT-3 equipments, and is completely interchangeable in either model.

A front view of the OCT-3 unit is shown in fig. 13.5 and a top view of the unit is shown in fig. 13.6. A dust cover (removed for these pictures) provides additional shielding for the monitor.

As shown in fig. 13.7, the equipment consists basically of a superheterodyne receiver with two cascade-connected limiters and a frequency-modulation detector or discriminator whose output is rectified and applied to a vacuum-tube-voltmeter. The a.c. output of the discriminator is proportional to frequency shift, and the vacuum-tube voltmeter indicates the amount of frequency shift in use at the transmitter. A unique feature of the equipment is that the frequency shift may be monitored continuously as well as by the *space* and *mark* difference-frequency method. The a.c. output of the discriminator is a function of the amount of the frequency shift being employed in the transmitter.

A more detailed block diagram is shown in fig. 13.8. Two self-contained crystals serve to calibrate the equipment and provide for accurate frequency-shift measurements. The calibrating crystals have 1000 c.p.s. frequency difference, and the monitor is adjusted for a reading of 1000 c.p.s. when these crystals are switched into the circuit. In addition, a very high order of frequency stability is maintained by operating the oscillator at a low frequency and using its harmonics for heterodyning with the incoming signal. A heat-insulated chamber houses the local oscillator to prevent temperature changes from affecting the accuracy of the calibration.

The equipment requires an external power source of either 115 or 230 volts a.c. at 50 to 60 c.p.s., and consumes about 150 watts.

Sensitivity

The Navy OCT unit is designed for an r.f. signal input level of 15 millivolts to 20 volts into an input impedance of approximately 75 ohms. From this, one can see that, although the front end of the unit is basically a receiver, it does not have a receiver's usual sensitivity. The reason for this is that it was designed to measure the frequency shift of a transmitter in the vicinity of the transmitter and not at some distant point.

Actually, one might be able to measure the frequency shift of a transmitter at a distance from the transmitter if the received r.f. signal could be amplified up to a level of 15 millivolts or more. This might be practical for local signals but it would hardly be worth the effort for greater distances.

14

TERMINAL UNITS

SOME of the basics of RTTY Terminal Units were covered in Chapter 4. The reader was also introduced to two of the earlier types of TU's which are still found in widespread use, the W2PAT and the W2JAV. They have been followed by others, many of which have been quite complicated and sophisticated. Even so, a great number of them have been modified versions of the W2PAT and W2JAV or at least used some of their basic principles of operation.

The popularity of the two earlier units, particularly the W2JAV, continues. The main reasons for this are: (1) These units, considering their simplicity, work rather well; (2) They are relatively easy to build and make work, if one cannot afford a "store bought' terminal unit; (3) A commercially built W2JAV unit, in transistor form, can be purchased at a very nominal price.

Let's cover a number of the better known Terminal Units that have followed. All of these have at least one common purpose and that is to improve copy.

What Is the Name?

The terminal unit is variously referred to as a converter, detector or RTTY receiver. The most common references, however, are converters or TU's. The term, receiver, is due to the similarity in the block diagram of a TU to an f.m. receiver. The term detector is not broad enough because the TU actually does much more than detect the signal.

The overall function of the TU is to *convert* the two-tone signal to d.c. pulses to operate the Teletype machine and the name converter is proper and suitable. The designation, Terminal Unit, is derived from the fact that it is the unit on the tail end of the electronic system or the terminal end.

The personal preference of the author is Terminal Unit since the term converter is already in use for defining a portion of the superheterodyne receiver.

The Transistorized W2JAV TU

Numerous articles have appeared in publications over the years covering transistorized versions of the W2JAV terminal unit and associated equipment. The first of these articles appeared in *CQ*, June 1958.[21] This early unit, designed by Phil Catona, W2JAV, was more concerned with miniaturization than just replacing the vacuum tube version of the unit. The new unit was so small that it was mounted in a W.E. polar relay housing.

A subsequent issue of *CQ*[22] published an improved version of the W2JAV converter, the circuit of which is shown in fig. 14.1. Present day units are much the same. A commercial version of this terminal unit is manufactured by Essco[23] as Model TU-1M (fig. 14.2) and is also available in kit form, TU-1MK.

Selector Magnet Driver

The W2JAV terminal unit was originally designed to be used in connection with a W.E.

[21] Kretzman, B., "RTTY Column," *CQ*, June 1958, page 74.

[22] Kretzman, B., "RTTY Column," *CQ*, February 1962, page 86.

[23] Essco, 324 Arch Street, Camden, New Jersey 08102.

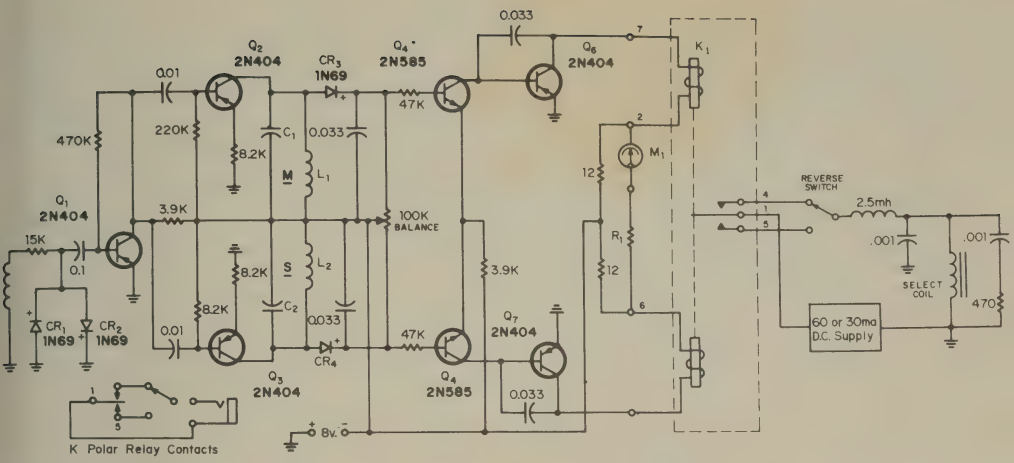


Fig. 14.1—Circuit of the W2JAV terminal unit with a W.E. 255A polar relay operating the selector magnets.

C_1—066 mf, 100v: Vary if necessary to tune L_1, to 2125 c.p.s.
C_2—.033 mf, 100v. Vary if necessary to tune L_2 to 2975 c.p.s.
K_1—Western Electric 225A with W.E. 18B socket.
L_1 L_2—88 mh toroid telephone loading coils.
M_1—Zero center milliammeter, 1-0-1 ma.
R_1—1000 ohms. Vary to get desired reading on M_1.
T_1—600 ohms to 19 000 ohms. FTR TF1A19 (W2EWL Special) or equivalent.

55A polar relay or a similar relay for keying he teleprinter selector magnet as shown in ig. 14.1. Because of the difficulty in properly djusting the polar relays and the natural endency to simplify, some amateurs try to rive the selector magnets directly from the erminal unit. A unit that would permit such peration was published in *CQ*[24] and is shown n fig. 14.3. Essco produced an improved com- nercial version shown in figs. 14.4 and 14.5.

The Essco unit derives its operating voltage rom a high voltage loop supply. The entire oltage is used to control one or two RTTY oops. In addition, zener diode Z_1 and re- istor R_{10} provide + 10 v.d.c. for operation of he bistable multivibrator. The flip-flop has a *mark* and *space* input and is used to control he one or two high voltage switching tran- istors. The input signals are at either of two evels, — 9 v. or ground. The flip-flop output s taken from the collector of Q_2. Thus the flip- lop converts two d.c. input voltages into a ingle output voltage with the two levels of) and —9 v.

The high voltage switching circuit takes the wo level voltage from the flip-flop and uses t to control one or two teleprinter selector nagnets. When the collector voltage of Q_2 rises bove 5 volts, zener diode Z_2 breaks down, causing base current to flow in Q_3 and Q_4. This base current is sufficient to saturate the wo transistors causing the two loops in their collector circuit to be completed and achieving a *mark* condition. When the Q_2 collector voltage is below 5 volts Z_2 remains non-conducting and Q_3 and Q_4 do not turn on. Therefore, the loops are not complete and a *space* conditions exist.

Resistors R_{13}, R_{14}, R_{17} and R_{18} are merely limiting resistors used to establish proper loop current. Resistor R_7 serves to keep the flip-flop in the *mark* condition in the absence of any signal, and thereby a quasi *mark* hold condition is achieved. This resistor may be removed from the board if *mark* hold is not desired. Diode CR_1 is a safety device used to prevent damage to the selector magnet driver in the event the loop supply polarity is inadvertently reversed.

An external loop supply is required to operate the solid state selector magnet driver. The

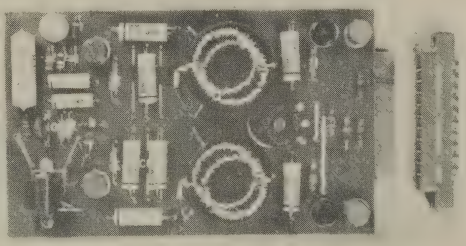


Fig. 14.2—Transistorized version of the W2JAV Terminal Unit, Essco Model TU-1M.

[24] Kretzman, B., "RTTY Column" *CQ*, November 1962, page 84.

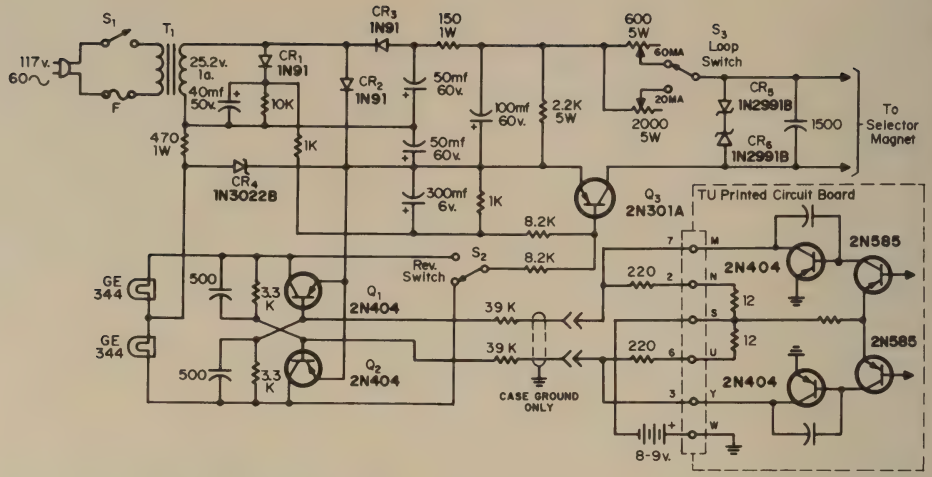


Fig. 14.3—A selector magnet driver unit that can be used with the circuit of fig. 14.1 to elminate the polar relay.

normal loop supply (110 to 130 v.d.c.) is adequate provided it can supply 80 ma d.c. for the single channel unit and 150 ma d.c. for the dual unit.

Narrow Shift TU

W2JAV also designed a transistorized converter for narrow shift operation (170 c.p.s.) instead of the standard shift of 850 c.p.s. This circuit is shown in fig. 14.6 and was previously published in *CQ*[25]. The input of the TU uses the same transformer as the wide band job and provides a 600 ohm input. The audio signal is then fed to the limiter clipper network consisting of R_1 and the two 1N69 diodes. The positive and negative peaks of the input signal are clipped and the resultant signal is capacitively coupled to Q_1, the first amplifier, a Class A stage. The output of Q_1 is capacitively coupled to Q_2, an amplifier with a center frequency of 2125 c.p.s. as determined by L_1 and C_1. The output of Q_2 is capacitively coupled to Q_3, the discriminator driver.

The discriminator circuit produces a d.c. voltage output whose polarity and amplitude are determined by the input signal frequency. The response curve of the TU is shown in fig. 14.7. The d.c. output of the discriminator developed across the 500K balance pot, is coupled to transistors Q_4 and Q_5 which ar

[25] Kretzman, B., "RTTY Column," *CQ*, September 1963, page 69.

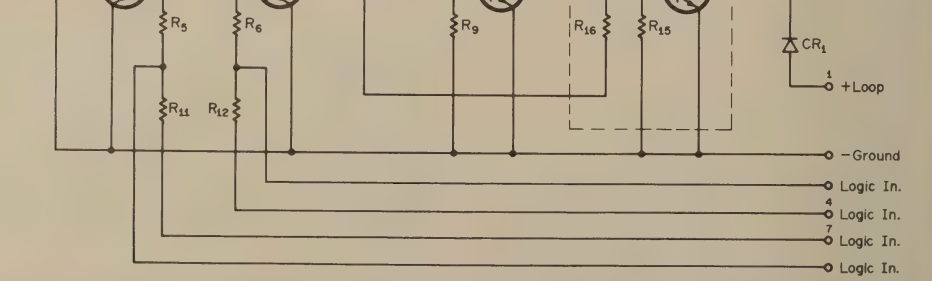


Fig. 14.4—Essco Model SM-1 twin channel solid state selector magnet driver circuit diagram.

rect coupled to transistors Q_6 and Q_7. Transtors Q_6 and Q_7 drive the polar relay which turn controls the selector magnet circuit.

The center scale 1-0-1 ma d.c. meter is adsted by the series resistor, R, so that with a) ma coil current it reads three quarter scale. he 12 ohm resistors in the collector circuits Q_6 and Q_7 should be a matched pair.

Inductors L_1, L_2 and L_3 are 88 mh toroids. nductor L_3 has a primary winding over it L_5), wound with 60 turns of #30 enameled ire. Inductor L_4 should be at least 3 hy or ore and as suggested in the original article an be the primary winding of a Lafayette R-97 or TR-120 transformer.

As with the wideband unit, the output of his TU can be connected to a selector magnet river unit (figs. 14.3, 14.4 and 14.5) in order o eliminate a polar relay.

Band Pass Filter

It was stated earlier that the purpose of erminal unit was to take the two RTTY f.s.k. ones from the output of the receiver and not nly convert them into d.c. pulses but do it in uch a way that perfect copy or as near perfect opy as is possible is obtained. In order to do his the TU must have a high degree of disrimination against band interference, noise nd other disturbances. In addition it must ope with selective fading, and reproduce a quare wave signal having a minimum of sigal distortion or bias telegraph distortion. A neans of reducing noise and interference is the se of an audio bandpass filter marketed by Essco. Its bandpass is from 2,000 to 3,000 ycles and 1,365 cycles wide at the 3 db points and 5,600 cycles wide at the 40 db points. It is lesigned for 600 ohm input and output and is

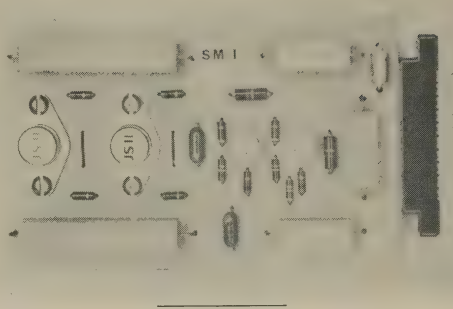


Fig. 14.5—Essco solid state selector magnet driver Model SM-1 twin channel.

intended for use between the receiver audio output and the TU input. Such a filter finds its greatest use with a poor receiver. For those who wish to homebrew one of these units the complete data for a similar filter is given in both The New RTTY Handbook[26] and an issue of *CQ*[27].

Other RTTY Terminal Units

Many other terminal units followed the W2JAV. Articles on some of the terminal units were written and published in either *CQ* or *QST* while data on other units was distributed on a limited basis, if at all. Time and space will not permit the review of all of the other terminal units other than to briefly mention a few.

The W4TJU[28] terminal unit is a simplified version of the W2PAT terminal unit with some modifications and is shown in fig. 14.8. It omits the dual diodes in the input circuit and starts with the two stage limiter amplifier, followed by a straight amplifier feeding a demodulator, an f.m. type ratio detector. This type of detector also performs a limiting action in addition to demodulating the input signal. It has a response characteristic almost identical to that shown in fig. 14.7 except that it will exhibit a wider bandwidth (850 c.p.s.).

Output terminals are provided for connec-

[26] Kretzman, B., *"The New RTTY Handbook,"* Cowan Publishing Corp., Port Washington, N.Y., page 165.

[27] Kretzman, B., "RTTY Column," *CQ*, January 1956, page 52.

[28] Wells, J. D. "Teletype Without Tears," *CQ*, December 1958, page 36.

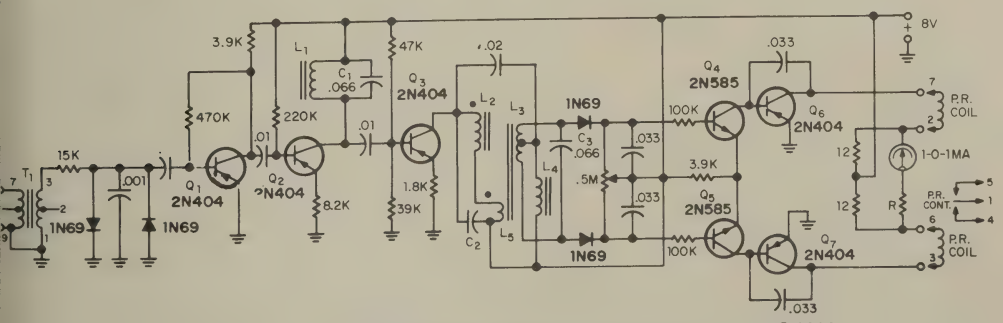


Fig. 14.6—Circuit of the narrow shift TU designed by W2JAV.

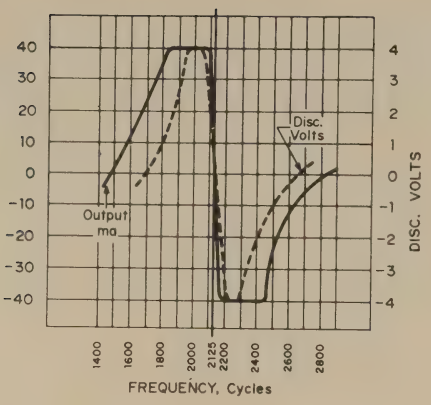


Fig. 14.7—Response curve of the narrow shift TU.

tion to a tuning oscilloscope which will be discussed shortly. The detector is followed by a d.c. amplifier which drives a 6AQ5 keyer tube. The output terminals were designed to feed the selector magnets directly for a neutral loop circuit.

The WØLQV TU[29], (the block diagram is shown in fig. 14.9), is somewhat different from any unit thus far described. It dispenses with the usual dual diode peak clipper circuit in the input and uses a bandpass filter with cut-off frequencies of 2,000 and 3,100 c.p.s. The bandpass filter is followed by individual tone filters for *mark* and *space*. The amplifier of each channel is in turn followed by a two stage limiter, another amplifier, and a voltage doubling (6AL5) detector. The detector is followed by a trigger driver stage, trigger stage, and a pair of parallel connected 6AQ5 tubes in the keyer stage.

The signals are combined at the output of the two detectors and fed through a low-pass filter with a cut-off frequency of about 140 c.p.s. Many present-day terminal units of various designs include such a low-pass filter. Some extend the cut off frequency down to 70 or 80 cycles. Such a filter reduces sharp impulse noise, beat notes due to interference and keying transients. It is highly recommended that a low-pass filter be incorporated into the terminal unit that you finally choose to build if it does not already have one. Low frequency beats of sufficient strength, from interfering signals, can trigger the terminal unit causing printing errors as can noise and other undesirable signals.

The WØLQV terminal unit has a built-in monitor scope. A scope monitor for the two RTTY tones is a must for any terminal unit although it is not necessary that it be built into the unit. The author prefers not to have the monitor scope built into the TU as it pre-

[29] McCoy, J. L., "Radioteletype Reception by Tone Conversion," *QST*, December 1960, page 11.

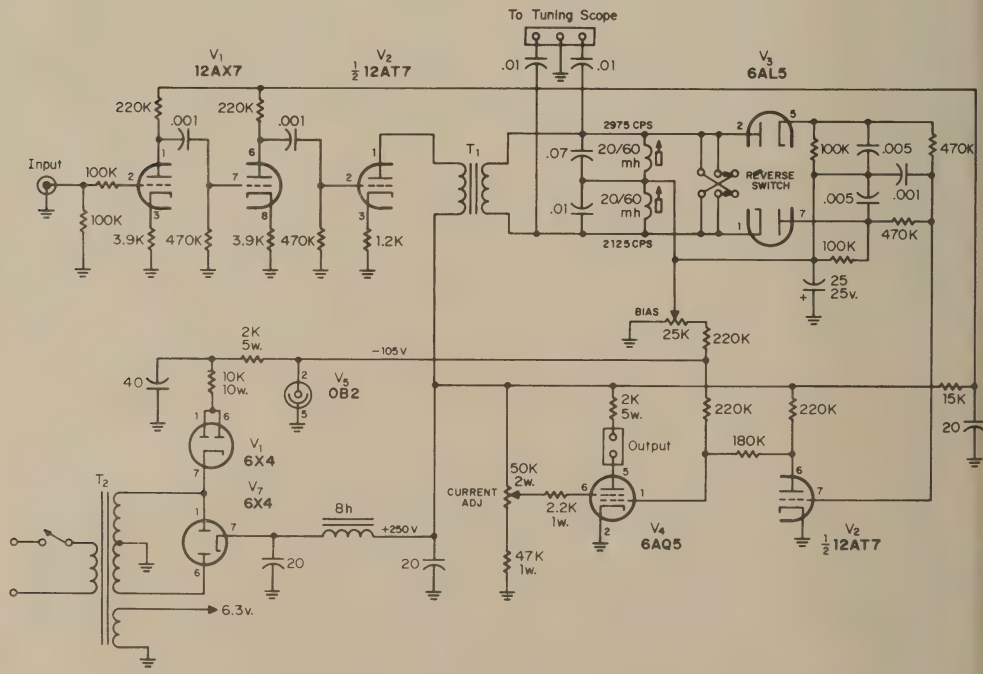


Fig. 14.8—Circuit of the W4TJU terminal unit. Transformer T_1 is a Merit A-2190, T_2 Merit P3148, the 20-60 mh coils Merit MWC-3 or equivalents.

ludes the use of the scope with any other unit r for other uses around the station. It isn't vise to build a scope monitor or anything else nto a TU if the observation of the RTTY rowd is any guide. They build and rebuild so nything built-in just complicates things that nuch more.

W5BGP TU

The W5BGP TU, from the southwest, is a vell known unit. It doesn't seem to be a copy f any other TU but as indicated in the origi- nal *CQ*[30] article includes features from the CV-89A/URA-8A surplus TU and the ubiqui- ous W2JAV TU. The input has a bandpass ilter, the construction of which is described in he parts list of fig. 14.10. The Essco filter lescribed earlier or the one described in The New RTTY Handbook will do as well. The ilter is followed by a two stage limiter ampli- ier, a discriminator amplifier (one for *space* nd one for *mark*) and then the discriminator. Switch S_2 is for NORMAL-REVERSE selection.

The output from S_2 is fed to the Axis Re- torer the function of which is to produce the ptimum output signal if the receiver is tuned o favor either *mark* or *space* and to key the veakest portion of a fading signal. Switch S_3 etween the Axis Restorer and the Keyer Input s to lock up the loop circuit for tuning. It does his by placing a small positive voltage on the grid of the keyer input tube when in the TUNE position.

[30] Guzick, M., "The W5BGP Teletype Terminal Unit," *CQ*, October 1961, page 44.

[31] Kretzman, B., *"The New RTTY Handbook,"* Cowan Publishing Corp., Port Washington, N.Y., page 94. *CQ*, March 1961 page 90.

[32] Kaufman, B., "A Filterless Terminal Unit for FSK," *QST*, July 1958, page 38.

[33] Guade F., "A New Approach to TU Design using a Limiterless Two-Tone Method," *RTTY*, June 1963. page 2.

Twin City TU

The Twin City TU[31] is still another well known and well copied TU. Complete construction details are given in *The New RTTY Handbook*. The unit is a simplified version of the W2PAT TU with a two stage input amplifier-limiter that drives a triode amplifier. The output of the 6C5 feeds a discriminator circuit which in turn drives a balanced 6SN7 keyer stage.

Other TUs

An interesting article, "A Filterless Terminal Unit for FSK" was published in *QST* in 1958[32]. It was indicated that since it contained no LC filters it would keep the printer operating even though the audio tones drifted within the range of 500 to 700 cycles. A follow-up article on this interesting TU covered modifications and refinements gained from building several of the TU's.

All of the terminal units discussed up to this point have been of the limiter-f.m. discriminator type. Most of the equipment used in commercial RTTY work for many years has been of this design. There is another type of terminal unit called the a.m. or *"two-tone"* type. For a number of years now, much experimenting has been carried on with this type of terminal unit in amateur RTTY circles across the country. One of the many amateurs experimenting with this type of terminal unit was K6IBE.[33]

K6IBE treated the two f.s.k. signals as a diversity pair of a.m. signals and there is no limiting. The K6IBE TU is particularly designed for improved copy in the face of extreme selective fading of the two received f.s.k. signals. The TU uses the slideback detector, a comb filter on the input and a Schmitt trigger stage driving the keyer stage. Probably no one terminal unit design has stirred up as much conversation as this one has. Fortunately, much

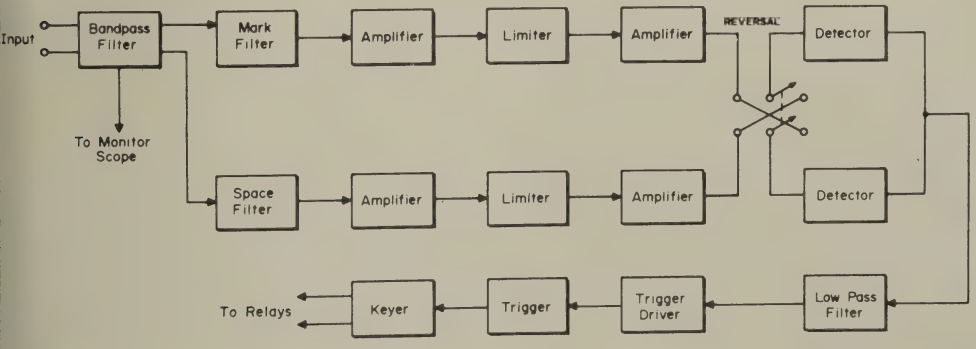


Fig. 14.9—Block diagram of the RTTY Tone Converter designed by WØLQV.

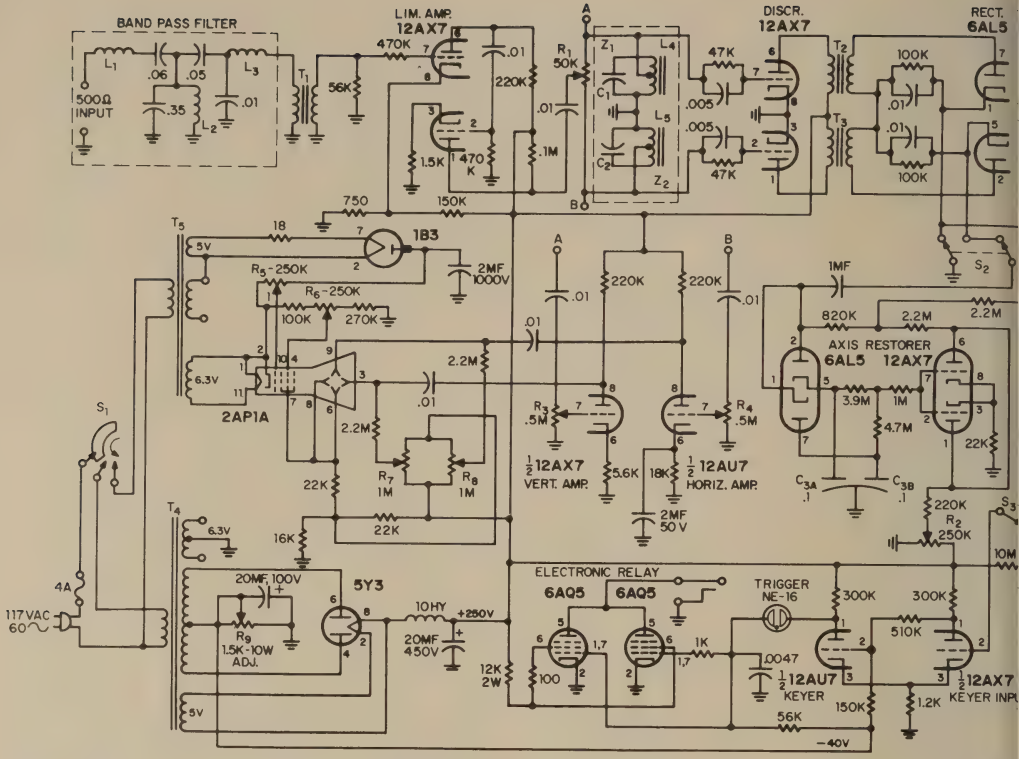


Fig. 14.10—Circuit of the TU designed by W5BGP.

C_1—0.066 mf C_2—0.03 mf

C_3—.1 mf Sprague Orange Drop Difilm Mylar

L_1, L_3, L_4, L_5—88 mhy torroids consisting of two 22 mhy windings on a core, connected aiding.

L_2—12 mh toroid consisting of one 22 mh winding with 13 feet of wire moved. Remaining winding remains open circuited and unused.

T_1—500 line to 100K. Stancor A4352 or equiv.

T_2, T_3—20K to 20K (may range from 1:1 to 1:3) Surplus Magnavox type 16C70-62 or Stancor A4774 wired for 1:1 Transformers T_2 T_3 must be identical.

T_4—350-0-350, @120 ma. 5V@3a, 6.3 v.c.t. @4.7a Thordarson 24R05 or equiv.

T_5—325-0-325 @40 ma, 5v@2a, 6.3v @2a Merit P3150 or equiv.

of the basic circuitry developed through the years following K6IBE's original article, was given in an article by K8DKC published in *QST*[34]. K8DKC stated that this particular unit was developed with the help of Keith Petersen, W8SDZ, with the guidance and assistance of Victor Poor, K3NIO, Chief Engineer of Frederick Electronics Corportion.

The K8DKC unit provides for an f.m. input section or an a.m. (two tone) input section with a switch to select one or the other. This is a very fine terminal unit but not exactly one that the beginner should tackle without first gaining experience with a more simple TU such as the W2JAV.

Tubes versus Transistors

Many of the TUs being built today are still of the tube variety rather than transistor type. The reasons for this are technical as well as simple reluctance on the part of many amateurs to move into what is for them a new technical area. Of the technical reasons the most important is that the selector magnets of the majority of the available machines operate at 100 to 200 volts and the earlier transistors operated at 9 to 30 volts. The need for the high voltage operation of the selector magnets was discussed earlier.

The development of high voltage type power transistors as used in the circuit shown in fig. 14.4 has eliminated this problem. In addition, the newer machines have selector magnets designed to operate with transistor driver units. These magnets have low voltage characteristics with high current ratings in the order of 500 ma. When these machines are made available to the amateur he will have no choice but to use transistorized terminal units.

[34] Hoff, I., "The Mainline TT/L F.S.K. Demodulator," *QST*, August 1965, page 27.

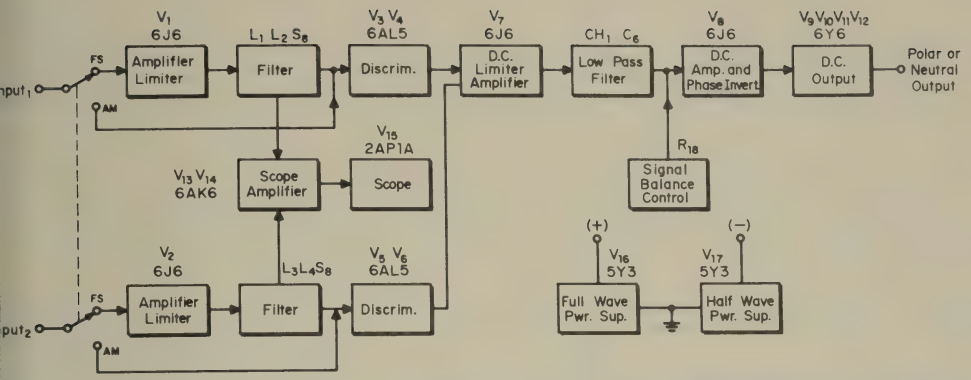


Fig. 14.11—Front panel view and block diagram of the surplus Boehme Model 5-C RTTY TU.

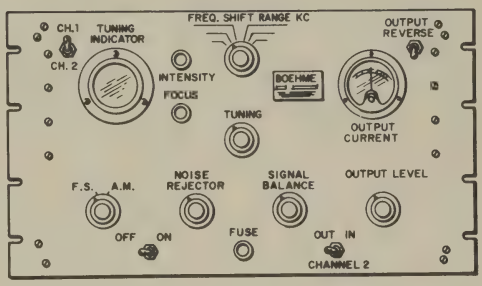
Surplus TU's

The U.S. Government has released an amazing amount and variety of surplus electronic gear since World War II. It is only natural that the beginner in RTTY may first cast a gaze in that direction.

Considerable RTTY gear was developed and used in World War II but unfortunately not much of it has found its way into general use in the amateur bands. In the first place there were no famous designs available in great quantities, readily adaptable to amateur RTTY use. The sheer size and weight rules out much of the gear.

Surplus units such as the AN/FGC-5, AN/GFC29, *etc.*, at about 5000 pounds qualifies them as elephants and white elephants at that, so far as ham use is concerned. The AN/FGC-1, a dual-diversity audio type terminal unit, is a respectable unit if you have room for a seven-foot high rack full of gear and weighing about 525 pounds out of the crate. There are a few smaller units such as the URA series and the FRA/FRE series. Most RTTY'ers do not consider that any of these compare to the AN/FGC-1. The main advantage in using the AN/FGC-1 TU is the dual-diversity feature as well as its a.f.c. feature; otherwise it is not worth the effort to go this route considering its size and weight.

A newer TU now appearing as surplus is the Boehme Model 5-C[35], which is only about ten years old. It fits a 19" rack and at 67 pounds isn't exactly light but it beats 5000 or 425 pounds. The 5-C unit can function on an unusually wide range of frequency shifts (200 cycles to 15 kc) as well as make-and-break keying of automatic Morse. It was used for intelligence work principally with the Army Security Agency. The front panel view and block diagram of the Boehme Model 5-C RTTY terminal unit is shown in fig. 14.11.



Commercial TUs

For those RTTYers who do not choose to build their own TU, a variety of commercial types are available. Some are built specifically for amateur use while others are made for industry and are adapted for ham operation.

Aquadyne Model RTY-1 TU

The Aquadyne RTY-1[36] radio teletype con-

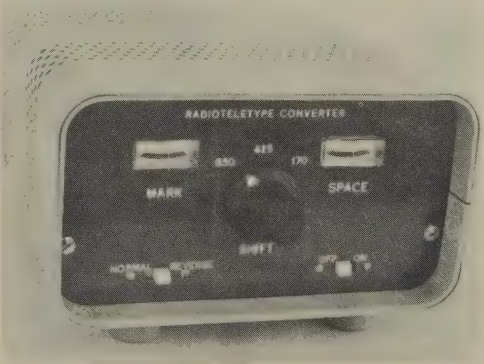


Fig. 14.12—Front panel view of Aquadyne Model RTY-1 TU.

[35] White, E. G., "Surplus Sidelights," *CQ*, July 1960 page 97.

[36] Aquadyne Inc., Box 175, East Falmouth, Mass.

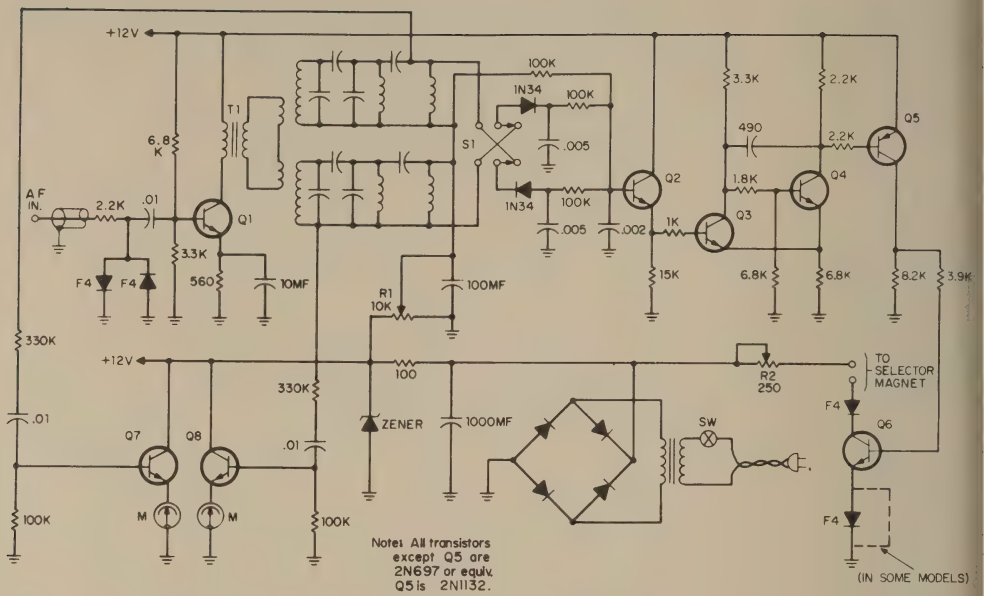


Fig. 14.13—Circuit diagram of Aquadyne RTY-1 TU.

verter is an audio filter type giving good discrimination against noise and unwanted signals. When it is used for f.s.k. signal reception on h.f. bands, the receiver b.f.o. is used to produce the desired audio tones from the received signal. On u.h.f. bands the converter is used for a.f.s.k. reception by simply connecting to the audio output of the receiver without the b.f.o. in operation. A front view of the Model RTY-1 is shown in fig. 14.12 and the circuit diagram is shown in fig. 14.13.

The input signal is fed to a limiter which clips the incoming signal to approximately plus and minus 0.5 volt. The output of the limiter is fed to a restricted bandwidth amplifier Q_1, which drives the pair of filter banks through windings on the input filter inductors. The filter consists of two channels, one for *mark* and one for *space* signals. The *mark* filter bank is fix-tuned to 2125 cycles. The *space* filter bank is tuned, dependent on the position of the SHIFT switch, to 2975 cycles for 850 cycle shift, to 2550 cycles for 425 cycle shift, or to 2295 cycles for 170 cycle shift. Use of a three section sub-critically coupled filter gives good selectivity for rejection of noise and unwanted signals. Excitation by noise at ½ and ⅓ filter frequencies is reduced by the use of a small coupling capacitor in the amplifier following the limiter.

The two filter bank outputs are connected to a pair of reverse connected diodes through the REVERSING *switch*. This provides output from one filter that is positive while the output of the other is negative. Time constant of the filter bank was selected to give additional rejection of noise pulses.

The pulses appearing at the diode outputs are coupled through an emitter follower, Q_2, to a Schmidt trigger circuit, Q_3, Q_4. *Threshold* bias on the trigger is adjusted by potentiometer R_1. A Schmidt trigger is either entirely on or off so that this circuit restores the square waveform desired for driving the selector magnet. The positive or negative puses from the diode output add to or subtract from the bias level on the Schmidt trigger so the circuit is switched on or off by incoming signals. The threshold control may be adjusted to simulate either the *mark* or *space* signal allowing copy on *mark* only or *space* only if desired.

The output square wave of the Schmidt trigger is fed to the keyer transistor, Q_5. The keyer transistor is biased so that it is either full on or full off, thus acting as a switch to drive the selector magnet. A diode in the emitter provides bias to assure complete cut off and a diode in the collector is provided to protect the transistor from the inductive kick fed back by the collapsing field of the selector magnet.

The tuning indicators are driven from the output of each filter bank by transistors Q_7 and Q_8 which isolate the loading effect of the meters from the circuit.

Alltronics Howard Model L TU

The Model L Telewriter TU built by the Alltronics Howard Co.[37] accepts audio fre-

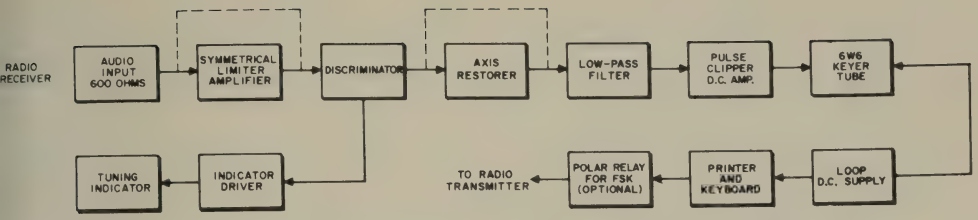


Fig. 14.14—Block diagram of Alltronics Howard Co. Model L TU.

quency shift tones with a center frequency of 2550 c.p.s., and frequency shifts from 100 to 850 c.p.s., depending upon the plug-in discriminator used. Unless otherwise requested, the Model L is equipped with a standard 850 cycle shift discriminator with *mark* set for 2125 cycles and *space* for 2975 cycles. A terminal unit is shown in fig. 14.14.

The Axis Restorer is particularly useful in copying differentially fading signals (i.e., *mark* fading at a different rate than *space*), and since it will be generally found that under these conditions a TU works better as an amplitude responsive device, provision has been made to disable the limiter by means of a switch. The use of the Axis Restorer automatically produces copy on *mark* only or *space* only, thus providing the advantages of frequency diversity reception. Also it will be helpful under conditions of interference, for if the *mark* channel is being interfered with, it may be possible to null out the *mark* signal with the crystal or *Q* multiplier, whichever device is present in the radio receiver, and copy will be obtained from the *space* signal only. The reverse will also be true, of course, if the interference is present on the *space* channel.

A polar relay may be plugged into an octal socket on the circuit board for the purpose of repeating the keyboard signals to key an f.s.k. unit in a transmitter. One winding of the relay is in series with the 20-60 ma loop circuit and the opposite winding is connected across a 10-30 ma bias supply. Thus a copy of the transmitted message is obtained directly, without the necessity of copying it through the receiver and TU.

The Model L Telewriter terminal unit has the unique feature of easy change from F.M. to A.M. operation. This is accomplished in the Model L by switching in the limiter.

It has become apparent that when propagation conditions result in severe independent fading rates of the *mark* and *space* signals, much better copy can be obtained from a.m. operation of the terminal unit. This condition is obtained by switching the limiter off. On long radio propagation circuits, selective fading is almost always present and, under these conditions, a.m. operation of the TU is recommended. However, if fading is not a problem, but noise and adjacent channel interference is present, changing to f.m. operation will usually result in better copy.

When the limiter is switched out of the circuit, the tuning indicator will be affected owing to the fact that the limiter tube also acts as an amplifier, and this stage of amplification has been eliminated. Readjustment of the audio output of the receiver may be necessary for satisfactory indicator presentation with the limiter switched to the OFF position.

Alltronics Howard Model M

The Alltronics Howard Co. is now marketing a completely new designed terminal unit that is completely solid state, using FET's. In addition, it is supplied with a heterodyne oscillator on the front end. Such oscillators are finding increasing favor with RTTY'ers building their own TU's.

With such an oscillator one need no longer worry if the sending station is transmitting the exact frequency shift to favor the two audio tone filters that a TU is supplied with. The heterodyne oscillator on the front end of the terminal unit makes it possible to beat any frequency shift that is being received, ranging from a few cycles up to 850 cycles. This is done by the use of only two fixed tone filters. This also eliminates the necessity of plug-in discriminator coils for various frequency shifts.

Tuck RTE-3 TU

The Tuck RTE-3 terminal unit is available in a rack-mounted panel, or in an enclosed cabinet. All connections to both types are from the rear.

The RTE-3 is an f.m. type of terminal unit with a built-in cathode ray scope monitor. The unit is designed to copy four different shifts. First, there is the normal shift (if it can be called normal any more) of 850 cycles per second, 600 c.p.s., 400 c.p.s. press frequency

[37] Alltronics Howard Co., Box 19, Boston 1, Massachusetts.

Tuck Electronics, 235 Market Street, New Cumberland, Pennsylvania 17070.

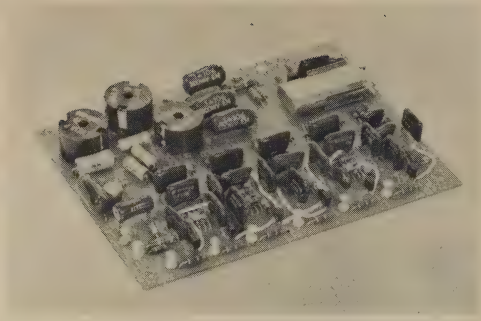


Fig. 14.15—Tuck K-100 series audio frequency shift keyers.

shift and the narrow shift of 170 c.p.s.

Tuck RTTE-3 TU

In addition, the Tuck Electronics Co. markets a terminal unit similar to the RTE-3 which is Model RTTE-3. The RTTE-3 includes a K103 keyer for a source of frequency shift keying for a transmitter. The keyer is of the a.f.s.k. type that generates the audio frequencies for the various shifts involved. For a shift of 850 c.p.s., the two audio tones are 2975 c.p.s. (*mark*) and 2125 c.p.s. (*space*). One of the K-100 series keyers is shown in fig. 14.15. These are a series of keyers or modulators which generate a two-tone stream of signals by a switch closure to ground. The tones are generated by a count-down circuit from a crystal oscillator. The count-down ratio is adjustable. The output, one volt into 500 ohms, is filtered and has about 1% harmonic distortion.

Frederick Model 1200 TU

Both the a.m. and f.m. terminal unit concept was discussed earlier. The Frederick[39] Model 1200 Terminal Unit incorporates both systems in the same unit with the option of selecting either system. This is accomplished by turning the limiter switch to the IN position to select the f.m. system and turning the limiter switch to the OUT position for operation as an a.m. unit.

The Model 1200 is normally supplied with *predetection* and *postdetection* filters for 850 cycles frequency shift for a *mark* frequency of 2125 cycles and a *space* frequency of 2,975 cycles. However, the unit can be supplied with card-type plug-in filters providing for a frequency shift operating range from 170 cycles to 2000 cycles. The normal baud rate is 45 to 50 (60 to 66 w.p.m.) but baud ranges of 30 to 300 can be supplied on special order.

The unit is solid-state throughout; a 130 v.d.c. loop supply is optional, otherwise, an external loop supply is needed to operate the printer selector magnet.

Decision Threshold Computer

A block diagram of the Frederick Model 1200 is shown in fig. 14.16. It embraces just about all of the most advanced techniques known to RTTY. Perhaps the most significant feature of this terminal unit is the Decision Threshold Computer (DTC). The decision threshold computer is a special patented circuit devised to cope with the signal fading problem encountered so much of the time.

Fading

There are various types of fading encountered. The most common type is frequency selective fading. This is a phenomenon by which signals of slightly different frequencies are not propagated with the same amplitude and phase relationship that they started out with as they left the transmitting station. This can happen

[39] Frederick Electronics Corporation, Frederick, Maryland.

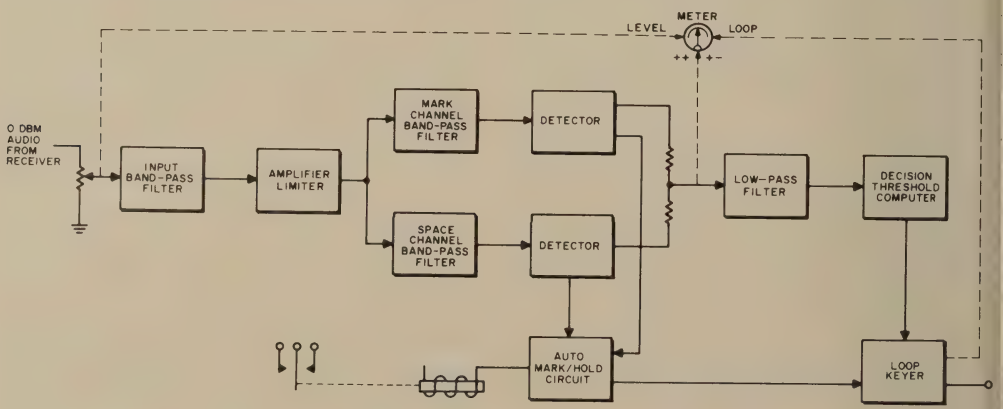


Fig. 14.16—Block diagram of the Frederick Model 1200 Terminal Unit.

ver most of the frequency shift range used or RTTY. Not until the frequency shift is own to about 100 c.p.s. can the two radio requency signals be expected to maintain a teady, unchanging amplitude and phase rela- onship.

Flutter fading is a very rapid type of fading roduced by an unstable propagation medium. ince the rate of fading is too fast for the me constants of the DTC circuit, optimum peration is obtained by placing the LIMITER witch in the IN position.

Back scatter is a phenomenon produced when he transmitted signal passes beyond the re- eiving zone, returns to earth and is then re- lected backwards into the receiving zone. Sig- als propagated in this manner are usually veak, and are recognized by a rapid fade or lutter. To counteract this type of fading, the LIMITER switch is placed in the IN position.

Operation Of DTC

The Decision Threshold Computer is a vari- ble threshold device which automatically de- ermines the half-way or transition point be- tween the *mark* and *space* signals. The DTC is particularly advantageous with fading signal conditions. If one channel should fade during keying, the signal would remain centered about he decision level. If the keyed signal should rest in a steady state (*mark* condition), the DTC would maintain a steady *mark* output. This latter operation provides maximum dis- crimination against impulse noise and sudden fades on the *mark* channel in the absence of keying. Output signals from the DTC are con- nected to a loop keyer for operating an ex- ternal teleprinter.

The DTC adjusts the transition point (deci- sion level) between *mark* and *space* signals in accordance with predetermined information concerning the amplitude of the two signals. Figure 14.17 illustrates what the DTC does. It is important to remember, during this dis- cussion, that either signal channel contains the complete message or transmitted information. At a point A, optimum receiving conditions exist, and the *mark* and *space* signals are of equal amplitude. The DTC thus determines the transition point to be half way between *mark* and *space*, or at the zero level. The de- cision level is represented by the dotted line.

Assume, now, that the *space* signal is af- fected by selective fading (area B), and, as a result, its amplitude is gradually reduced to the zero level. Through the action of the DTC, the decision level is raised approximately half- way between zero and maximum *mark* ampli- tude. During this time, all information is ob- tained from the *mark* channel both accurately and without interruption. After the fading con- dition has ended, the *space* signal regains its

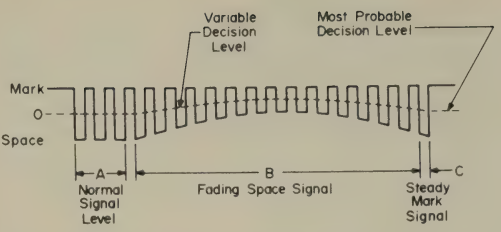


Fig. 14.17—Graphical demonstration of de- cision levels in the Model 1200 DTC.

original amplitude, and the decision level re- turns to the zero position.

If the received signal goes to a steady *mark* and remains there (area C), the decision level does not remain at the half-way point as it did for the fading space signal. Instead, the deci- sion level falls to zero. The reason for this is that the DTC does not know the actual level of the space signal, since it cannot accumulate valid data in the absence of keying. Therefore, for lack of better information, the DTC as- sumes that the *space* level is the same as the mark level, and returns the decision level to zero. This is the most probable level; the DTC will always return to it for a steady state signal.

Automatic Mark Hold

An additional output from each channel de- tector is used to control an automatic *mark*/ hold circuit (Auto M/H). This circuit func- tions as an auto-start system, and returns the TU output to the *mark* state when the received signal drops below the noise level, or when non-f.s.k. signals such as Morse code or noise are present.

The *mark*/hold circuit functions only when the AUTO M/H-NORMAL switch is in the AUTO M/H position, the LIMITER switch is in the IN position, and the MODE switch is in the N posi- tion. Basically, the automatic *mark*/hold circuit functions to open or close the demodulator out- put loop via contacts of a relay.

TU Summary

By now, the reader should be aware of the fact that there are two general concepts by which an f.s.k. signal may be viewed. One is the f.m. concept which is by far the most com- mon and its popularity with both commercial and amateur RTTY'ers dates back to the very beginning of frequency shift keying. The other concept is that of two a.m. signals which isn't exactly new but many are giving it another and closer look. The changing amplitude of *mark* and *space* signals, due to selective fading can cause errors in a limiter-discriminator type terminal unit even though the signal-to- noise ratio may be relatively high.

Sometime back it was stated that the tele-

type machine is an *on-off-operated device* and for every unit of the code it is going to consider it as either *mark* or *space*. In the absence of sufficient signal or information as to whether the code unit is actually *mark* or *space* it is certainly conceivable that it can be wrong fifty percent of the time. One may well wonder if the f.s.k. system is any better than the early make-break-make system using a single tone, when with the two-tone f.s.k. system one tone disappears. In so doing it serves to gum up the works for the other tone since it is essential that both tones be present in the output of the discriminator. When the *mark* or *space* signal is lost the limiters ahead of the discriminator are captured by the random noise or other interference which then appears in the output of the discriminator in the place of the desired *mark* or *space*. It can be noted that limiters only make things worse when the peak signal does not exceed the peak noise. The action of the limiter stage is such that the output of the discriminator tends to have a constant output voltage of random noise when the signal fades out. These noise pulses may pass on through the terminal unit and cause the printer to produce garbled copy.

Error-free copy dictates that both the *mark* and *space* signal pulses be well above the noise. Furthermore, another signal on another frequency, other than that of *mark* or *space*, can cause errors even up to 100 per cent depending upon the signal strength. QRM, like noise, will capture the limiter away from the desired signal.

Two-Tone Concept

It was pointed out that the f.s.k. two-tone a.m. concept, along with such terminal units, has received renewed attention during the last several years. A number of the leading RTTY'ers have done a great deal of developmental work on the f.s.k. two-tone a.m. terminal unit during this time. Probably the most publicized work was that done by K6IBE, just covered. K6IBE conservatively states that most tests of his unit indicated that it is from *two to ten times better* on an error rate count basis than the conventional limiter-discriminator type TU. W6NRM states that the error rate for a similar terminal unit was as much as 1/20th or 1/30th that of the conventional limiter-discriminator type TU.

There has been no complete agreement in the ultimate superiority of the two-tone a.m. terminal unit over the f.m. discriminator type from published data, to date, nor is this likely to happen any time soon. However, there seems to be a growing feeling that the two-tone a.m. concept appears to have more promise. Unquestionably, there are operating conditions where it is desirable to use the f.m. type of TU while other conditions may favor the a.m. type. Still, it must be said that there are conditions where neither unit has an appreciable advantage above the other. The ultimate would be to incorporate both types into one TU design with a simple switch to readily change from one type to the other.

Perhaps the most significant feature of the f.s.k. two-tone a.m. concept is its frequency diversity feature. Selective fading can have a devastating effect on a conventional TU whereas it can become an advantage under the two-tone concept by incorporating diversity receiving techniques into the design of the a.m. type TU. Generally speaking, without going into specific details, this means copying on one tone alone, especially when the other is either gone or much weaker. It also means that this process may be reversed, copying on first one tone and then the other. Under such conditions, the change from one to the other may be at a slow or fast rate, depending upon signal fading conditions. The TU circuitry is usually so designed that this is done electronically.

It has been general knowledge for many years that two high frequency radio signals only a few hundred cycles different in frequency (well within the 850 cycle amateur RTTY chift) can each have selective fading of the two frequencies that are independent of each other. For instance, the *mark* frequency can be increasing in signal strength while, at the same time, the *space* frequency can be decreasing in signal strength or *vice versa*. This can become a distinct advantage. As the frequency difference between these two r.f. signals decreases, the fading of the two signals becomes less independent until finally they fade together. It is generally considered that this happens when that difference becomes 100 to 200 cycles. For this reason, most of the low f.s.k. experimenting is done at 170 cycle frequency shift or higher. The developmental work on f.s.k. two-tone a.m. TU's has been centered mostly on signal *filters, detectors,* and especially on *decision forming circuits.*

15

THE RTTY STATION

For the beginner there is always the big question, "What do I need to set up a station?" The simplest thing to do is to start with one teleprinter machine, preferably a page printer and a TU. Store bought TU's are getting more and more plentiful and priced over such a wide range that one can find a unit to fit almost any pocketbook. The chances are good that the beginner may still wish to build his own. In this case, it should be a relatively simple one. There are a number of reasons for this. First, one can get on the air or start copying sooner, and it just could satisfy your needs. If you do eventually build a superduper TU the experience gained with a simple unit will not have been wasted. After having been on the air for awhile and become familiar with the equipment and RTTY operating procedures one can begin to think of additional equipment. Many hams have operated for years with a Model 26 or Model 15 machine and a home-built W2JAV terminal unit. Some of these are our most active RTTY'ers. It certainly does not take an elaborate layout to have fun and fully enjoy RTTY. Rag chewing, for instance, does not usually bring into play a stack of punched tapes of canned information which require tape machines. Canned information is used more for new contacts and for contests.

Setting Up An RTTY Station

Setting up an RTTY station can be a relatively simple procedure or it can become quite involved, just like a c.w. or phone station. It depends entirely upon the individual and how much equipment is involved and what the operator wishes to accomplish. Added pieces of equipment and extra operating options increase the complexity of the interconnecting circuits as well as the switching circuits.

About the simplest layout one can have is one machine (page printer), a TU and a simple frequency shift keyer for keying the oscillator of the transmitter. A block diagram of such a layout is shown in fig. 15.1.

Figure 15.1 is composed of three basic circuits:

1) Control Circuits: The control circuit includes the circuits and components necessary to actuate the antenna changeover relay, activate or disable the receiver and transmitter.

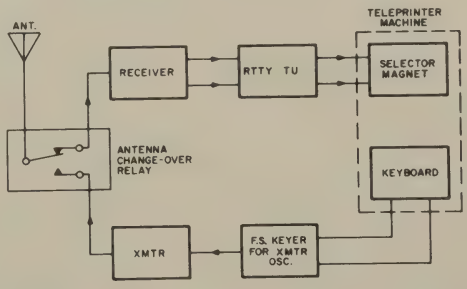


Fig. 15.1—Block diagram of a simple RTTY station layout.

2) Local Loop: The local loop consists of the TU output circuit, the local loop power supply and the printer selector magnets.
3) The F.S.K. Circuit: This area, as explained earlier, shifts the frequency of the transmitter v.f.o. using either the keyboard contacts or a polar relay or shifts the tone of an audio oscillator for a.f.s.k. operation on the v.h.f. bands.

Control Circuits

Any active amateur understands the general requirements for setting up a phone or a c.w. station. There are such things as switching the antenna from transmitter to receiver, speaker muting, protection of receiver input while transmitting, switching high voltage on and off as required and other functions depending upon the equipment and individual requirements. Many of these same switching operations are also involved in the operation of an RTTY station.

Local Loop

The beginner in RTTY work usually has a bit of difficulty with the local loop. In the first place, he often supposes that it is some fixed circuit and that everyone but him seems to know all about it and no one seems to have been thoughtful enough to publish the circuit.

The local loop is just that part of an RTTY station's wiring that connects the teleprinter to the rest of the station equipment. The circuit can become more complicated if more than one page printer or other teleprinter equipment is involved. A simplified local loop is that made by W5BGP and shown in fig. 15.2. It will be noted that it actually contains two local loops. One is the operating loop used for sending and receiving operations. The other is used to cut tape when neither transmitting or receiving, or it can be used for cutting a tape answer while receiving on the operating loop.

Some of the general requirements of a local loop may be envisioned by reviewing the keying portion of the TU circuits of the various units covered in Chapters 4 and 14. Actually, most of the basic ingredients of a typical local loop were included in the circuit of the polar relay keying test set shown in fig. 7.3.

F. S. K. Circuits

F.s.k. circuits were covered in Chapter 3 and a number of typical circuits were given. Also discussed were dry contact keying versus wet contact keying. In Chapter 8, in connection with fortuitous distortion under the Keyboard Distortion section, some of the problems of keying directly with the keyboard transmitter contacts were also discussed.

Local Copy

When designing the circuit arrangement for your station it is not necessary to make provisions for local copy of what is being transmitted but most operators do, and it is a good practice. Some operators make local copy of while others switch the selector magnets from the TU circuit to the keying circuit while transmitting and back again to the TU when receiving. This switching is usually done automatically by a relay operated from an extra contact on the antenna changeover relay.

Off the air monitoring is indicated in fig. 15.1 since the receiver is not disabled when transmitting. The lead from the antenna changeover relay to the receiver should be shielded and no longer than necessary so that r.f. pickup is reduced. Even then it may be necessary for the operator to lower the r.f. gain of the receiver when transmitting, de-

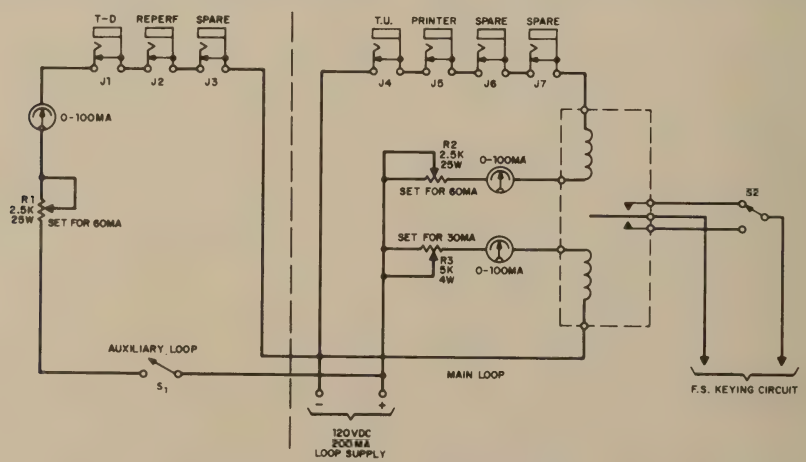


Fig. 15.2—Simplified local loop circuit.

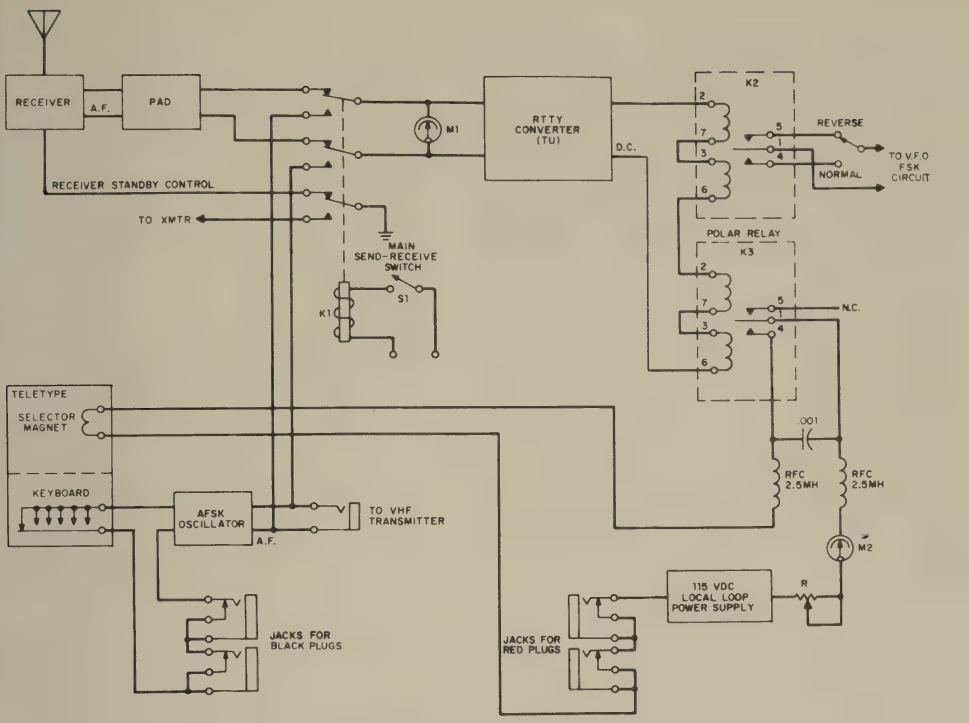


Fig. 15.3—An RTTY station control circuit.

pending upon the receiver sensitivity, transmitter power, the antenna and its distance from the operating room, in order to keep from overloading.

In Chapter 3, fig. 3.11 showed a frequency shift keying circuit that also included the selector magnet. Local copy can be made of the signal being transmitted with such a keying circuit as this. All that is needed is an extra relay with the proper number and arrangement of contacts to switch the selector magnets from the TU output circuit to the keying circuit and back again.

Control Circuits

It has just been pointed out that there are hardly any two local loop circuits that are alike. This also applies to RTTY control circuits since they depend upon the equipment being used, both as to kind and quantity, as well as the various functions the individual operator wishes them to perform.

A typical control circuit that includes the three areas just described is shown in fig. 15.3. The heart of this control system is relay, K_1 which is manually controlled by S_1, the SEND-RECEIVE switch. The applied voltage to this relay circuit is determined by the coil characteristics of K_1. It may be a.c. operated and powered from the line or a plate relay type in which case it may be energied from the local loop power supply.

The receiver output (marked *A.F.*) should have an impedance of 500 to 600 ohms. The function of the block marked PAD is to attenuate the output so as not to overload the TU input as it does not require a large signal.

The output from the attenuator pad is fed to the relay where it is switched into the TU in the RECEIVE position. The output of the TU controls two polar relays, K_2 and K_3. Polar relay K_2 is used to frequency shift key a v.f.o. when transmitting. Relay K_3 keys the teletype

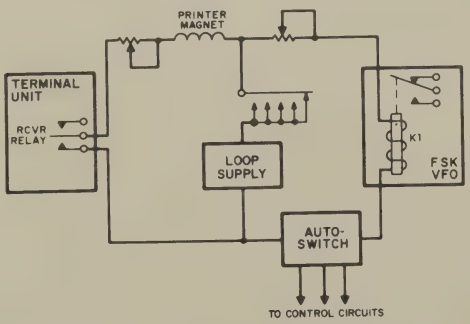


Fig. 15.4—Basic block diagram of an automatic control circuit.

printer selector magnet on the local loop circuit.

When K_1 is energized for tansmit operation the contacts pull down and connect the output of the a.f.s.k. oscillator to the TU input, cut off the receiver and turn on the transmitter. The keyboard of the teletype machine shifts the a.f.s.k. oscillator frequency which is fed to the TU input. The TU output controls K_2 which provides f.s.k. operation in the transmitter v.f.o. Relay K_3 prints the transmittel message on the page printer through the local loop.

The function of the r.f. chokes and capacitors connected in the K_3 circuit is to prevent contact hash from interfering with reception.

An antenna changeover relay is not shown in fig. 15.3 but is assumed to be part of the switching circuit of the transmitter.

The output of the a.f.s.k. oscillator is available from J_4 to modulate a v.h.f. transmitter directly.

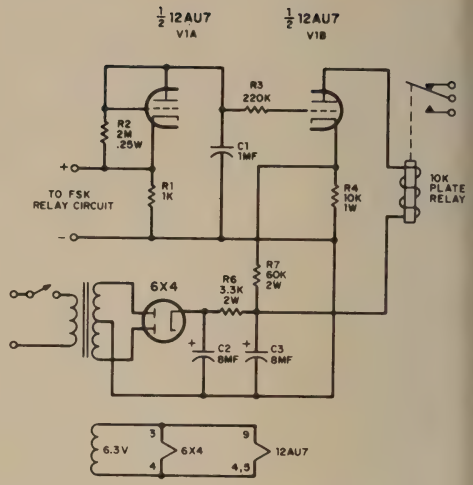


Fig. 15.5—Circuit of the automatic control shown in fig. 15.4.

Automatic Control

The c.w. station has break-in operation and the phone station has vox. K2DHE devised an automatic control circuit for RTTY that eliminates the need for any manual switching. The basic block diagram of the arrangement is shown in fig. 15.4. When the keyboard of the teletypewriter is at rest its contacts are closed. Current flows in the printer magnet circuit and through the relay in the f.s.k. circuit of the v.f.o. The current that flows through this relay, K_1, also flows through the automatic switch circuit which then disables the receiver and turns on the transmitter.

The circuit of the automatic switch is shown in fig. 15.5. When the keyboard is at rest, the RECEIVE position, the current through K_1 also flows through R_1. The resultant voltage drop across R_1 cuts off the diode V_{1A} and C_1 charges through the 2 meg resistor. The voltage across C_1 is applied to the grid of V_{1B} causing V_{1B} plate current to rise and pull in the plate relay.

When the keyboard is operated to transmit a message the K_1 circuit is broken. It opens the loop through K_1 and removes the positive voltage from the cathode of V_{1A} so that only its plate is positive. The diode then conducts and discharges C_1 through the low resistance path of R_1 and V_{1A}. This places the grid of V_{1B} at zero volts and the fixed positive voltage on the cathode of V_{1B} cuts V_{1B} off. This releases the plate relay which switches to TRANSMIT. This occurs within 3 milliseconds of initial operation of the keyboard. Random typing will not allow time for C_1 to charge through the 2 meg resistor which constitutes a long time constant circuit. When typing is stopped for about 2 seconds the charge on the capacitor will build up to a point where the relay in the plate circuit will trigger and go back to receive.

The arrangement shown in fig. 15.4 prints local copy while transmitting. In this circuit the keyboard keys both the send loop and the printer while the receive relay keys only the printer. Because of this it is necessary to lock the receive relay on *mark* while transmitting.

Interconnecting Essco Units

Essco terminal units and selector magnet solid state keyers were covered in the previous chapter on terminal units. A block diagram showing a suggested layout of Essco units is

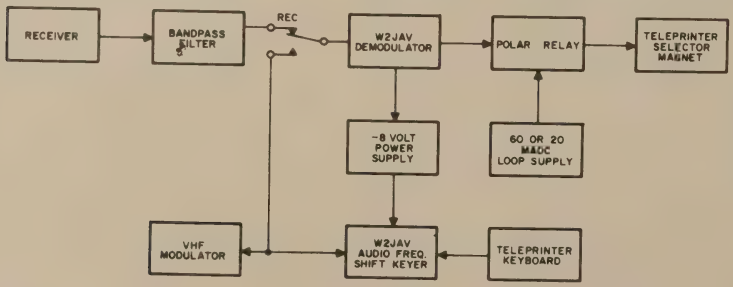


Fig. 15.6—Simplified block diagram showing the interconnections of the Essco RTTY units for v.h.f. operation.

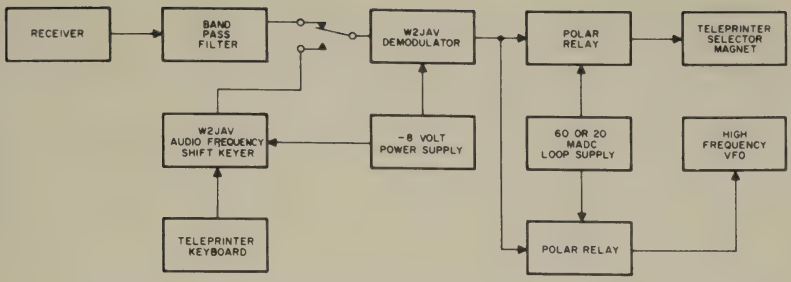


Fig. 15.7—Block diagram of the Essco units set up for h.f. operation.

given in fig. 15.6 for v.h.f. operation and fig. 15.7 gives a block diagram of a suggested layout for high frequency operation. A more detailed block diagram using Essco units is shown in fig 15.8.

The TU-1M is designed for use with the Essco SM-1 Selector Magnet Driver, the WE-255A Polar Relay or both. The SM-1 (SM-1K) is the more desirable from electrical and mechanical standpoints. The SM-1 dual unit is capable of driving two 60 ma selector magnets or any combinations of 60 or 20 ma selector magnets. It will function with machines employing holding or pulling magnets with little or no loss in range. In some instances the range may be increased over a polar relay. No filtering or spark suppression is required and the radiated r.f. noise is at a minimum. It is smaller in size and initial cost. No mechanical adjustment to this device is required. The polar relay will function adequately, but requires adjustment and must be properly oriented. There is no objection to using a polar relay to key the f.s.k. circuit of a transmitter. When the SM-1 and polar relay are both employed as shown, it will be necessary to remove the connections from pin 7 and 4 of the SM-1. This will disconnect the polar relay load simulator which is not required when a polar relay is used. When the SM-1 is used independently, the connections will be the same as shown, less the connections to the polar relay. As many as 5 SM-1 units may be connected in parallel using the circuit as shown. When the polar relay is used independently to key the selector magnets, the connections to the SM-1 should be disregarded. Two polar relays may be used in parallel or in series, one to key the f.s.k. circuit, and the other to key the selector magnet. The total TU-1M current will increase by a factor of 2 when two polar relays are connected in parallel. The TU-1M will operate with any type of teleprinter, including the Models 14, 15, 19, 26, 28, Kleinschmidt, Siemens, etc.

A WE-255A Polar Relay can be used with the Essco TU-1M demodulator. For best performance, this relay must be properly adjusted. An improperly adjusted relay will result in unsatisfactory operation. To reduce wear of the contacts, a spark suppressor should be employed across the relay contacts. This will also help in the reduction of r.f. noise. A recom-

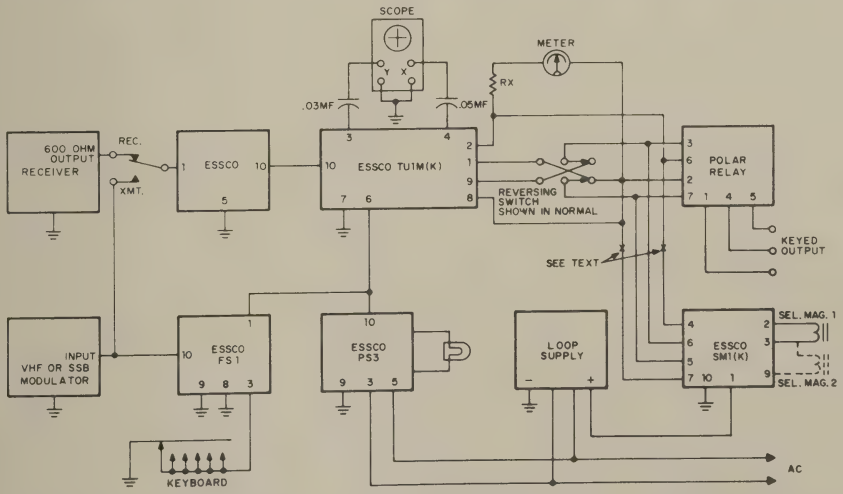


Fig. 15.8—Detailed block diagram of the interconnections for the Essco RTTY units.

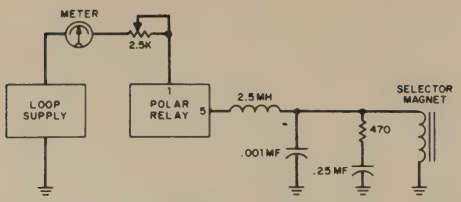


Fig. 15.9—A suggested relay contact spark suppressor to be used with a WE-255A polar relay.

mended spark suppression circuit is shown in ig. 15.9.

Provisions have been made to allow connec- ion of the Essco TU-1M to an oscilloscope or monitoring purposes. (See fig. 15.8.) Ter- minals 3 and 4 of the demodulator may be connected to the vertical and horizontal am- plifiers of an oscilloscope. The ground connec- ion from the oscilloscope must be made to erminal 7 or damage to transistors and diodes will result. As a further protection to the de- modulator, the *mark* and *space* scope outputs should be capacitively coupled to the scope. Use 0.033 mfd capacitors at 400 v.d.c. Make he leads to the scope as short as possible to reduce the detuning effect on the *mark* and *space* filters but do not use shielded wire.

Narrow Shift C.W. ID

One of the things that plagues an RTTY'er s the necessity of using c.w., along with tele- type, for the proper identification of his sta- tion. At first, the FCC required that the other station call also be included. This part of the rule has since been withdrawn. Even so, the necessity of sending one's own call by c.w. does complicate things. The switch from teletype to sending c.w. by the usual c.w. make and break system can cause the receiving ma- chine to run open or print gibberish or do both depending upon how the operator accom- plishes his ID keying.

Ideally, one should manually key his trans- mitter for c.w. operation by shifting the fre- quency as with RTTY. This makes it possible to keep the machine from running open. In addition, if one uses a very narrow shift, it is possible to keep the machine from printing anything at all during the ID process. With narrow-shift c.w., the teleprinter remains in an idling (*mark*) condition. This is most desirable.

A number of f.s.k. circuits were given in Chapter 3 in which the frequency shift, in most instances, was controlled by adjusting the value of a resistor such as R_1 in fig. 3.8. Maximum shift is obtained when R_1 is zero.

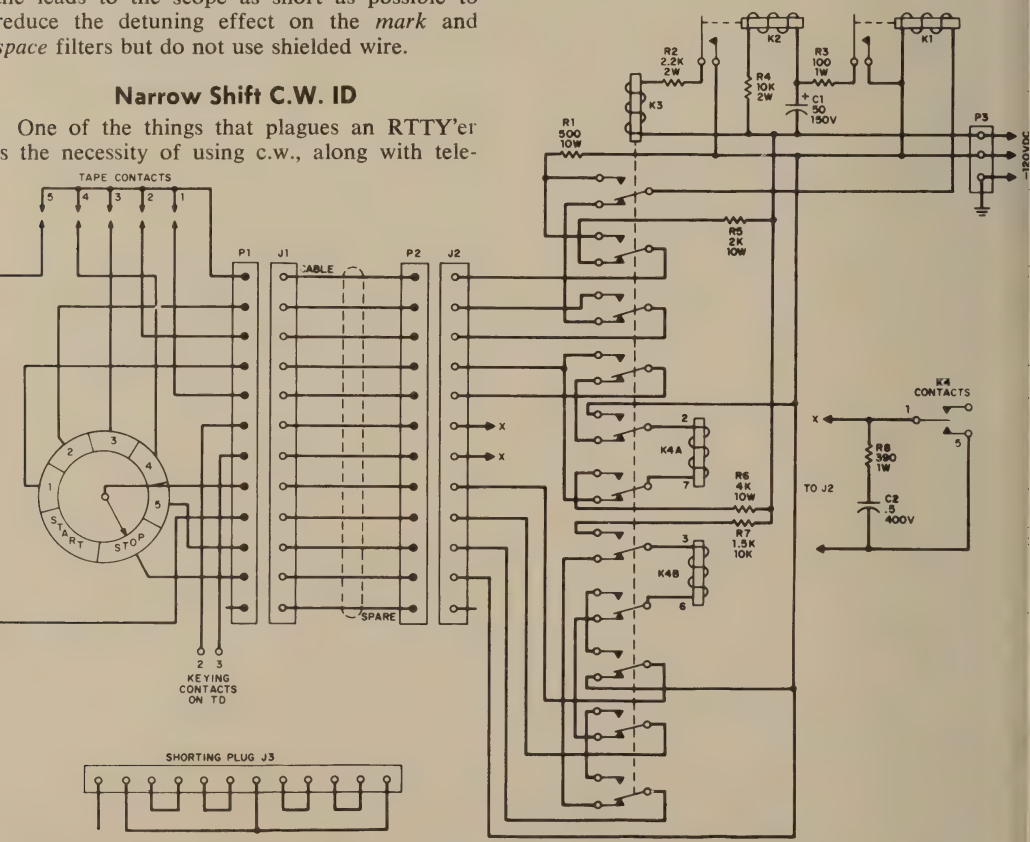


Fig. 15.10—The WØLQV circuit of the relay system modifications needed on the model 14TD for c.w. and regular teletype operation on the same TD using a single tape.

Control R_1 is usually adjusted for some desired frequency shift and left alone. A small portion of the required resistance of R_1 may be a fixed resistor. Alternately shorting and unshorting this small resistance value with switch S_1 closed will cause a small frequency shift. The FCC frowns on a frequency shift of less than 100 cycles for c.w. identifying purposes since any shift less than this would make identification difficult.

The f.s.k. circuit of fig. 3.8 may not be applicable to all transmitter v.f.o. circuits. The principle for narrow shift ID as outlined above may be equally well applied to any one of the other f.s.k. circuits given in Chapter 3.

Automatic ID

For a number of years, the RTTYe'r has been intrigued with the possibility of punching a tape so that morse code resulted. Various approaches to this have been made. The necessity for using Morse c.w. by manual means for ID purposes not only is a nuisance but strikes a pretty low blow to the ego of any RTTY'er. Some pretty elaborate systems have been devised to do this c.w. ID chore by automatic or semi-automatic means. One such system is that devised by WØLQV.[40] The circuit of the relay system and modifications needed on the Model 14 TD for c.w. and regular teletype operation from a single tape and on the same TD are shown in fig. 15.10.

WØLQV explained in the original article that to produce the desired Morse code the proper characters must be punched into the tape to energize channels one and five in a manner that will create dots and dashes in a time ratio of 1 to 3. It will be noted from standard teletype coding the letter E is produced from a pulse from channel one only, the letter T from channel five only and the letter Z from channels one and five. If a tape punched with the letter Z is passed through the transmitter-distributor the polar relay will close when the armature passes over segment one. The relay will remain closed until the armature contacts segment five and will then open. The keyed circuit is thus closed for 0.088 seconds. If the tape is punched with the letters E and T in succession the armature will close the polar relay at segment one. The relay will remain closed during the remainder of the revolution. At this point the tape will advance to the letter T and the relay will open on segment five producing a keying period of 0.251 seconds and very close to three times the previous period. Using the letter Z for dots and the letters E and T in succession for dashes with a single blank between characters and two blanks between words, a code speed of approximately 15 w.p.m. will develop."

The above scheme is to be used only in connection with punching a tape and not to be attempted live. A person would have to get pretty adept with the keyboard to do this live.

Autostart

It was only natural that someone come up with the question: "Why be there while all this is going on?" There *is* no need for one to be there if all is in order. It is possible to leave the receiver turned on and tuned to some specific frequency along with the TU and teleprinter turned on also, with the thought that any message coming along will be duly recorded. Many RTTY'ers do exactly this and others do it with modifications. In most instances, only the receiver and terminal unit are left turned on while the motor of the printer is turned on and off by the received signal. Such a system, called a continuous monitoring system, can use a considerable amount of paper if the frequency is very active with little or none of the copy being of much interest to the receiving operator.

Another system utilizes a time clock to turn on the receiver and TU with the received signal turning on the printer motor. Such a system is called an Autostart System. Actually, there is a bit more to it than this, depending upon the operator. For instance, one may set the system to turn on the receiver and TU at one or more specific times and turn them off the same way. In addition, one may have added circuitry (time delay) that will turn off the receiver and TU within a minute or so (adjustable) if no signal is present at the beginning or if the signal disappears (ends) any time along the way.

Obviously there is no single way that the Autostart feature should be or is accomplished. Here again, a lot depends upon the operator. One finds more interest in the Autostart feature in the v.h.f. bands than on the lower frequency bands. In either instance it adds a new dimension to amateur radio. If you are at work or otherwise occupied at net time, there is no need to miss what goes on. Just set the Autostart, come back a few hours later and there it is.

Just one word of caution. Most radio amateur equipment is operated intermittently and much of it is built with this in mind. Be sure that any equipment that is to operate unattended will not get unduly hot. In addition, fuse all critical circuits and be sure that time delay and relay circuits are reasonably fail-safe. Fusing should not be done with whatever fuses are

[40] McCoy, J. L., "Dual Identification From Your Tape Distributor," *CQ*, Nov. 1966, p. 74.

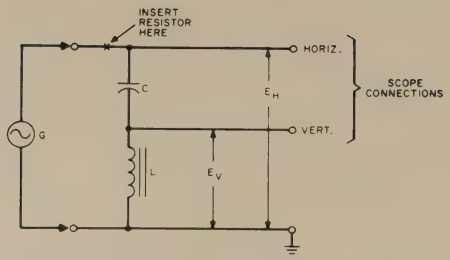


Fig. 15.11—Basic phase detection circuit for an RTTY scope monitor.

on hand but with the lowest possible value in every instance. Just any fuse may save the house from burning down but it may not keep the receiver or TU from being damaged.

A number of Autostart systems have been covered in the amateur literature such as the Autostart for the Twin City TU.[41] Many of the Autostart systems in use are versions of this system. Some RTTY'ers have gone a step farther by using crystal controlled receivers and WWV to synchronize the *mark* carrier frequency of the transmitter at each end.

Monitoring

The terminal unit will not be in operation very long before it is realized that something more than the audible monitoring of the signal is needed. Trying to tune in an RTTY signal properly by just listening to it can be a frustrating experience and certainly leaves much to be desired. Sooner or later the newcomer to RTTY will get around to some type of visual monitoring system.

The first thing that comes to mind to use for visual monitoring is a scope or one of the "Magic-eye" tubes such as the 1629, 6AF6 and 6AF6G electron-ray tube or the 6FG6 tube.

It will be recalled that the author provided for a simple method of scope monitoring the *mark* and *space* signal in the polar relay keying test set covered in Chapter eight. Scope traces of *mark* and *space* were also shown. This was done by taking the scope pick-up from a jack (J_6 or J_8) across a 50 ohm resistor placed in the circuit for this purpose. The trace thus obtained was of a fixed frequency (23 cycles) signal used for test purposes.

The test set just mentioned as well as the W2PAT and W2JAV terminal units covered in Chapter five and other terminal units use neon bulbs that flash when an RTTY signal is tuned in. Such neon bulbs, used in triggering devices, can give some measure of aid in tuning in the signal if they are mounted on the unit so as to be readily visible. They too, however, leave something to be desired.

Besides the electric eyes and the scope methods there have been other visual methods developed that used a meter indicating device.

There are probably more RTTY'ers using the scope method of monitoring than any other. It seems, however, that the electric eye method is finding more favor. Perhaps the relative size of the scope versus the electric eye is the deciding factor, especially if the monitoring device is built into the terminal unit. There are certain advantages to either building the visual monitor into the TU or leaving it out. Building it in makes the TU more complete as a unit but at the same time it complicates the construction and increases the size of the unit. It also precludes the use of the monitor with any other TU.

Monitor Operation

The heart of a scope monitoring system for RTTY signals is a series resonant circuit, as shown in fig. 15.11, and the phase relationship of certain voltages associated with that circuit. The voltages under consideration are E_V and E_H as indicated. The generator, G, is the audio output of the receiver. Consider a *mark* audio frequency of 2125 c.p.s. and a *space* frequency of 2975 c.p.s. with a shift of 850 c.p.s. The center frequency would be 2550 c.p.s. If capitance C and inductance L are resonated at the 2550 frequency, the scope trace will be an ellipse similar to (a) fig. 15.12. This is due to the 90 degree phase relationship between the two voltages at the resonant frequency. A resistor of suitable value placed at point X in the circuit of fig. 15.11 virtually reduces the ellipse to a straight vertical line, as shown in (c) fig. 15.12. Incidentally, this line is vertical because it has no horizontal axis voltage component and, therefore, indi-

[41] RTTY Column, CQ, June 1961, p. 82.

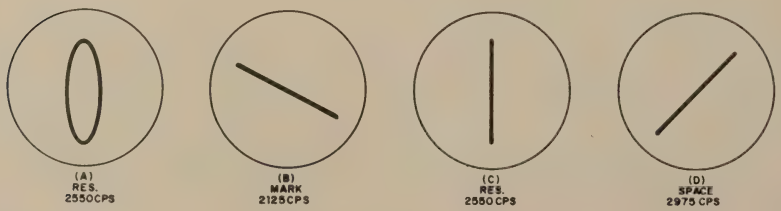


Fig. 15.12—Scope traces as they appear for resonance (A and C), below resonance (B) and above resonance (D).

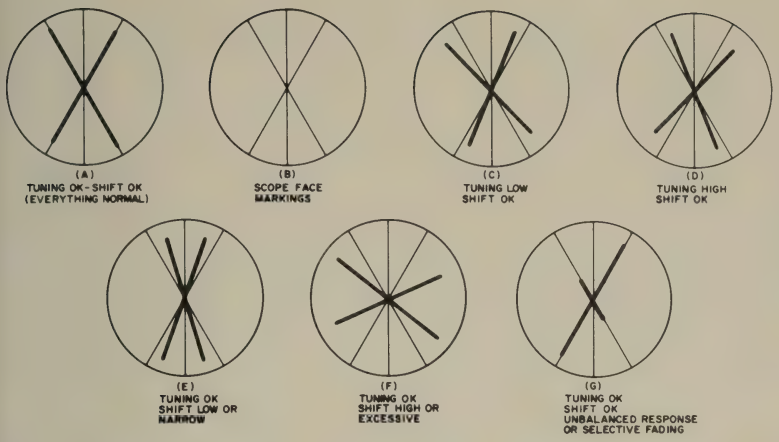


Fig. 15.13—Mark and space signal traces as seen on a monitor scope.

cates the center, series-resonant, frequency of 2550 c.p.s.

At a frequency below resonance the vertical trace of (c) is tilted to the *left* as shown in (b) fig. 15.12. Likewise, above the resonant frequency, the vertical trace is tilted to the *right* as shown in (d) fig. 15.12.

From this it is seen that the degree of tilt of the trace becomes an indicator of frequency deviation at any point of fixed horizontal and vertical amplifier gains. Manipulating the vertical and horizontal gain controls at any fixed frequency shift, such as 850 c.p.s., can also change the angle of the traces. For instance, by making the horiontal amplification relatively large, compared to the vertical gain, it is possible to have an extremely wide angle aperture between the *mark* and *space* traces even though the actual frequency difference (shift) may be relatively small.

The angular displacement of the *mark* and *space* traces for any particular shift involved is somewhat of a personal choice but most operators use something less than 45 degrees. Many settle for about 30 degrees as shown in (a) of fig. 15.13. A clear plastic cover for the face of the scope should be marked as shown in (b) fig. 15.13. Traces for various conditions of shift, tuning and receiving are shown in (c) through (g) of fig. 15.13.

The resistor to be placed in the circuit of fig. 15.11, at point *X*, should be about 10K and adjustable. It can be adjusted to equalize the length of the traces. The value of *C* and *L* for resonance at 2550 c.p.s. is about 0.0075 μ and 500 mh. These values would change accordingly with other center resonant frequencies.

Tuning For Scope Monitor

A word about tuning. With no signal, noise, or interference tuned in on the receiver, the pattern on the scope is only a small dot. Seldom does one have such a perfect condition. If there is no RTTY signal around, chances are that there will, at least, be noise and possibly speech present. Speech and noise create a scope pattern similar to (a) in fig. 15.14. Speech and noise, along with a weak RTTY signal, may give a scope pattern similar to (b) fig. 15.14. As one tunes into the edge of an RTTY signal (either side) with a receiver, the dot on the scope is replaced by a small cross that increases as the signal is tuned in. The cross attains its maximum size when the signal is fully or correctly tuned in on the receiver.

In fig. 15.13 (g) a typical trace was given for a condition of: (1) Tuning OK, (2) Shift OK, and (3). Unbalanced response or selective fading. Suppose that the shift was off considerably from the shift necessary to match the audio tone filters of our TU. We would have to either "straddle tune" our receiver, causing considerable attenuation of both tone signals, or else tune for maximum of one tone or the other. In such an instance, one could get such a pattern as shown in fig. 15.13 (g) showing that we tuned for maximum *space* signal causing considerable attenuation to the *mark* signal.

RTTY Cross Pattern Monitor

The system of scope monitoring, just described, is that of the phase relationship of certain voltages associated with a series reso-

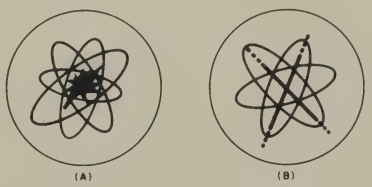


Fig. 15.14(A)—Pattern of noise and speech with no RTTY signal. (B) Pattern of noise, speech and a weak RTTY signal.

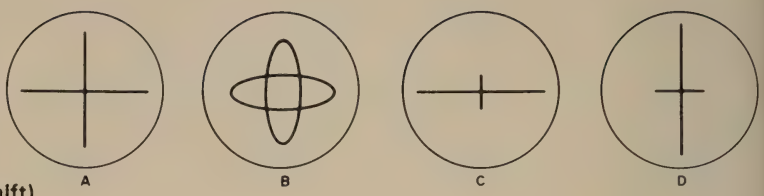


Fig. 15.15(A) — Perfect RTTY signal. (B) Crossed ellipses due to low Q for TU filters. (C) Receiver peaked on space (Incorrect shift). (D) Receiver peaked on mark (Incorrect shift).

nant circuit. With such a system, the two traces (*mark and space*) of an RTTY signal formed an X pattern on the scope.

Many RTTY'ers use a scope monitoring system in which the two traces of an RTTY signal form a *cross* or 90 degree relationship with each other. Usually the vertical trace represents *mark* and the horizontal trace represents the *space* signal, as shown in fig. 15.15 (a).

Terminal units such as the W2PAT and W2JAV, covered in Chapter Five, have parallel tuned circuits for *mark* and *space* respectively. A simple procedure in obtaining a *mark* and *space* trace respectively, would be to lightly couple (so as not to disturb the circuit) through a small (.001 mf) capacitance, to each resonant circuit. This should be done by connecting the *space* coil to the horizontal plate of the scope and the *mark* coil to the vertical plate of the scope. One word of caution. So many TU's use filter circuits with such a low *Q* that one may obtain two crossed ellipses such as (b) instead of the crossed lines of (a) fig. 15.15.

The above condition may be remedied by improving the *Q* of the TU filter circuits, which incidentally, should also improve the operation of the TU (up to a point). This may not always be easy to do, so one may simply put a stage of amplification in between the TU and each scope deflection plate. The plate circuit of each amplifier (*mark* and *space*) should have a resonant circuit, such as found in the TU, for the respective tone. It would also be advisable to put a gain control in the grid circuit of each of the two amplifiers.

There is one further word of caution. If this system of monitoring is applied to the f.m. type of terminal unit, the tone filters follow a signal limiting stage or stages which may obscure what is going on. In this case it would be better to connect the two monitoring amplifiers ahead of the limiting action which may mean transformer coupling to the audio output of the receiver. An a.m. type terminal unit would not present this problem as it does not use limiter stages. Actually one may, depending upon the unit, find it acceptable to connect the monitor following the limiters in an FM type of TU. The best thing to do is to experiment with the TU to determine the best place to connect the monitor.

RTTY signal traces for the X type trace scope monitor covered in figs. 15.13 and 15.14 generally hold also for the cross type monitor. A few of the signals encountered with the cross scope monitor are shown in fig. 15.15. These should be compared to the equivalent pattern for the X type scope monitor.

Frederick Model 1250 Display Unit

Some type of visual monitoring, indicating the presence and condition of the two tones, is an almost must for any RTTY'er, as has been pointed out. Two types of scope patterns for visual monitoring of RTTY signals have just been covered. One was the X scope pattern and the other was the cross scope pattern. The following unit for monitoring the *mark* and *space* signals gives two parallel vertical traces on the face of the scope for the two signals. The Frederick Electronics Corporation manufactures the Model 1250 Display Unit, a companion to the Model 1200 TU. A general view of the Model 1250, along with the Model 1200 Demodulator, is shown in fig. 15.16 and a block diagram of the unit is shown in fig. 15.17.

The Model 1250 Display Unit features a cathode ray tube presentation which may be utilized in either one of two basic modes. In the Frequency Mode, the f.s.k. tones, derived from the channel band pass filter outputs of the demodulator, are mixed and furnished to

Fig. 15.16—General view of the Frederick Model 1250 Display Unit for monitoring tones of an RTTY signal. It is mounted in a cabinet with the Model 1200 FSK Demodulator.

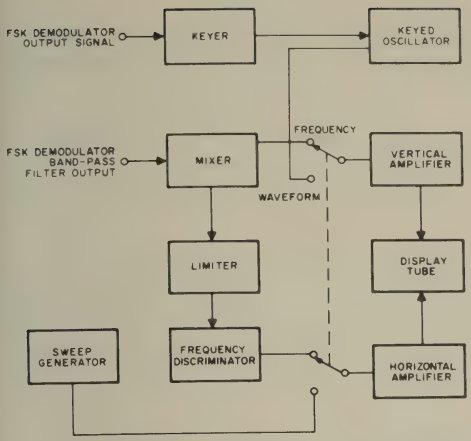


Fig. 15.17—Block diagram of Frederick Model 1250 Display unit for monitoring RTTY signals.

provide vertical deflection to the display tube proportional to signal amplitude. The f.s.k. bandpass filter outputs are also mixed and applied to a discriminator furnishing horizontal deflection proportional to the input signal frequency. The display, in the Frequency Mode, will serve as a visual aid in receiver tuning. When the receiver is properly tuned, the resultant pattern will be a pair of vertical lines representing the f.s.k. tones. These vertical lines are spaced approximately two inches apart along the base line, one to the left and one to the right of center. Receiver tuning should be optimized by adjusting for a simultaneous maximum of both vertical traces.

In the Waveform Mode, the output signal of the f.s.k. demodulator is displayed in the form of a keyed tone to permit observation of signal quality as applied to the teleprinter circuit. An internal sweep circuit which furnishes horizontal deflection during this mode, may be triggered or free running, as selected by a front panel switch. Sweep length is continuously adjustable by front panel control from 80 to 250 milliseconds.

Additional front panel controls include: Focus, Intensity, Horizontal/Vertical Positioning for the cathode ray tube, and a Channel Selector. This latter control permits the display unit to be used, for example, with up to ten Model 1200 terminal units.

Monitoring Other TU's

The block diagram of fig. 15.8 of the Essco units, shows a meter, *M*, inserted between points 2 and 5. This should be a center scale milliammeter or microammeter. The resistor, R_{12}, should be 500 ohms for a 1 ma movement and 1000 ohms for a 500 microampere movement. The meter is primarily intended as a means of indicating the polar relay current. The meter, however, will also serve as a good tuning indicator.

The cross pattern monitor (scope) system can also be used with the Essco Model TU-1M or any other terminal unit where it is possible to connect to the *mark* and *space* filters.

The V.T.V.M. Monitor

Perhaps the simplest monitor of all for RTTY signal tones is the v.t.v.m. This is done by measuring from the hot side of the *mark* filter to the hot side of the *space* filter.

For the W2JAV Terminal Unit, shown in fig. 4.6, this means connecting to the hot end of L_1 and L_2. Since one end of each coil is grounded, the v.t.v.m. case must not be grounded. If the v.t.v.m. cannot be ungrounded, an appropriate a.c. scale of a v.o.m. may be used. One may also make up a special measuring circuit, consisting of a diode rectifier, resistor and sensitive microammeter such as 50 or 250 microamperes.

Maximum reading is obtained when the shift is right and both tones are properly tuned in. Selective fading will cause the meter level to drop. The meter level will also fall if the signal level drops below the limiting action of the TU. The meter may also be used to set the balance pot, R_1, of the W2JAV terminal unit of fig. 4.6. A proper setting of R_1 is indicated by a steady reading of the meter. If the RTTY signal is improperly tuned to one side or the other, this is indicated by a flicker or erratic action of the meter. If the meter does not go up to its customary maximum value with the signal properly tuned in, it can indicate a non-standard shift or at least a shift that does not match the one for which the TU is designed.

Tuning Indicator and Squelch

An offshoot or variation of some of the RTTY monitoring systems just described is an

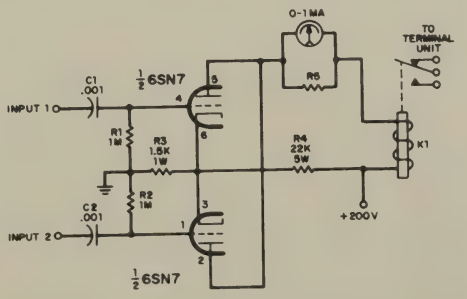


Fig. 15.18—Circuit of the RTTY tuning Indicator. All resistors are ½ watt except as noted.

RTTY tuning indicator and squelch.[42] This device also uses a meter as an indicator. The meter is in the parallel connected plate circuit of two tubes whose individual grids are connected to the *mark* tone circuit and the *space* tone circuit. This is shown in fig. 15.18. The author of the original article states that the two grids, through C_1 and C_2, must be connected into the TU circuit at a point where at least 3 volts r.m.s. of signal is available. In an audio type of TU the connection is made after the filters but before the rectifiers. Connection to an f.m. type of TU, operating as an extension of the receiver's i.f. strip, is usually more difficult. If the output of the detector gives two positive voltages referenced to ground, one for *mark* and one for *space*, then the meter circuit can be connected there, omitting the capacitors C_1 and C_2 to permit direct coupling. In all other cases, it will be necessary to add a second discriminator transformer in parallel to the original one and follow it with a rectifier circuit that will give the two positive d.c. voltages. An arrangement of this nature is shown in fig. 15.19.

In the meter circuit, fig. 15.18, one triode receives an a.c. signal when the *mark* channel is activated, and the other triode receives a signal when the *space* channel is activated. The tubes are set close to cut off by the voltage divider, R_3 and R_4. Thus, with no signals coming in the meter reads close to zero. As the signals are received, the tubes begin to conduct on the positive half cycles of the signal and the meter, which is too sluggish to follow the a.c. variations, gives a smooth indication of amplitude.

In the f.s.k. operation, there is a signal on one of the two grids but never on both at the same time. Because of this a steady reading of the meter develops at some point up the scale, depending on the level of the incoming signal. As long as the signal is perfect, the reading will be steady. If there is a signal in only one channel, (tuned half out of position, wrong shift, or a c.w. signal and not f.s.k.) then the meter will follow the keying and lash back and forth across the dial. If the signal is way off frequency or absent, the meter will read low and follow the background noise.

If a squelch is desired, a plate circuit relay can be added. It must be of high quality for good results, having at least a 5000 ohms coil resistance. The object of the relay is to have it cause a steady *mark* condition in the teleprinter loop circuit when the relay has no current flow through it. This can be accomplished in several ways depending on the circuit of the TU being modified. For all TU's that use a polar relay to drive the printer, perhaps the simplest method is to connect the normally closed contacts on the squelch relay across the active contacts in the polar relay. Make this connection out in the loop, however, not right across the polar relay as you may spoil your hash suppression.

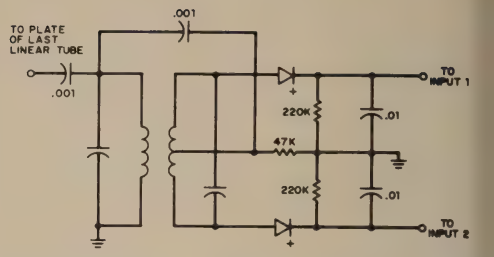


Fig. 15.19—The indicator circuit of fig. 15.18 must use the discriminator circuit shown above when operated with an f.m. type TU. Capacitors C^1 and C^2 in fig. 15.18 must be omitted when used with this circuit. The i.f. transformer, above, must be of the correct frequency for the equipment used.

If a keying tube output is being used, some connection can usually be worked out to short the grid to ground; connect it to a bias source tapped from somewhere, or else create a steady current flow in the tube with the relay contacts.

If a *mark* hold, or steady *mark* switch is incorporated anywhere in the TU's design, connect the relay to duplicate its function.

The Identimer

It is possible to go on and on covering various combinations of RTTY station layouts, local loops, control circuits and various devices associated with RTTY work. For instance, there is the Identimer.[43] With the Identimer, every 9 minutes and 45 seconds, the transmitted signal is interrupted for 15 seconds; during this time the station call is automatically transmitted by m.c.w. in the a.f.s.k. mode or f.s.k. in the s.s.b., mode, During this period, the *mark* tone remains on the air and therefore the receiving printers are locked up and do not miss a letter. Also, there is no garble as is the case with present voice or keyed identification.

Automatic Carriage Return And Line-Feed

The automatic carriage return and line feed for the Model 15 was covered earlier in Chapter 3. This was a kit put out by Teletype Corporation and was all mechanical. Custom Devices, Inc., recently announced an all electric system for the Model 19 or for the Model 15 with an outboard TD.

[42] **Combs**, C. H., "An RTTY Tuning Indicator and Squelch," *CQ*, March 1965, p. 25.

[43] Custom Devices, Inc., 439 S. Canal St., South San Francisco, California 94080.

In operation, the signals for carriage return and line feed not only control your printer, but are transmitted to control the receiving printers. One switch is mounted for the end of the line and is adjustable for operation from the 60th to the 72nd character. A second switch is mounted for the start of the line and a Black Box is connected to the keyboard, the input of the TU and also to the TD relay.

Re-Inking Ribbon

Any ham that uses his teletypewriter very much soon finds out that his local copy soon looses its fresh look as the ink on the printing ribbon gets used up. Soon after that, his local copy looks more like the 20th carbon of a report and the ink is so thin that it is hard to read. This means a good supply of fresh ribbons or else some means of re-inking the ribbons. A number of ribbon re-inking methods have been devised and a few devices for doing this have been advertised in *CQ* and *RTTY Journal*. One firm advertising such a device is Telemethods International.[44]

[44] 3075 East 123rd St., Cleveland, Ohio 44120.

16

FCC RULES, OPERATING PROCEDURES

THE following portion of the Federal Communications Commission rules and regulations governing the Amateur Radio Service include those rules pertaining to amateurs engaged in radio teleprinter operations. These excerpts are by no means complete.

The rules and regulations are amended or changed from time to time. In the past they have not only been changed, but re-numbered as well. One can refer to the Federal Communications Commission Rules and Regulations, Volume VI, Part 97 for complete details. The FCC Rules and Regulations are grouped into ten volumes and sold in volume units by the Superintendent of Documents, Government Printing Office, Washington, D.C. The price of the volume entitles the purchaser to receive its amended pages for an indefinite period.

Part 97.1 **Basis and Purpose.** The rules and regulations in this part are designed to provide an Amateur Radio Service having a fundamental purpose as expressed in the following principles:

(a) Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.

(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

(c) Encouragement and improvement of the amateur radio service through rules which provide for advancing skills in both the communication and technical phases of the art.

(d) Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.

(e) Continuation and extension of the amateur's unique ability to enhance international good will.

Part 97.79. **Who may operate an amateur station.** An amateur radio station may be operated only by a person holding a valid amateur operator license. Such station may be operated by the licensee only in the manner and to the extent provided in his amateur operator license. Persons other than the station licensee, when operating such station, may operate it only to the extent and in the manner authorized to the licensee of the station and not exceeding the operating authority of such person's own amateur operator license When an amateur station is used for telephony or radio teleprinter transmissions, the station licensee may permit any person to transmit by voice or teleprinter, provided during such transmission call signs are announced or transmitted as prescribed by para. 97.87 and a duly licensed amateur operator maintains actual control over the emissions, including turning the carrier on and off for each transmission and signing the station off after communication with each station has been completed.

Part 97.87 **Transmission of call signs.**

(1) The operator of an amateur station shall transmit the call sign of the station or stations (or may transmit the generally accepted identification of the network) being called or communicated with, or shall identify appropriately any other purpose of a transmission, followed by the authorized call sign of the station transmitting:

(i) at the beginning and end of each single transmission or;

(ii) at the beginning and end of a series of transmissions between stations having established communications each thansmission of which is of less than three minutes duration (the identification at the end of such a series may be omitted when the duration of the entire series is less than three minutes), and;

(iii) at least once every ten minutes or as soon thereafter as possible during a series of transmissions between stations having established communications, and;

(iv) at least once every ten minutes during any single transmission of more than ten minutes duration.

(2) The required identification shall be transmitted on the frequency or frequencies being employed at the time and in accordance with the type of emission authorized thereon, shall be by either telegraphy using the International Morse Code, or telephony, except that, when a method of communication other than telegraphy using the International Morse Code or telephony is being used or attempted, the required identification shall be transmitted by that method and only the call sign of the transmitting station need be transmitted either by telegraphy using the International Morse Code or by telephony.

Part 97.89 **Points of Communications.** An amateur station may be used to communicate only with other amateur stations, except that in emergencies or for test purposes it may also be used temporarily for communication with other classes of stations licensed by the Commission, and with United States. Government stations. Amateur stations may also be used to communicate with any radio station other than amateur which is authorized by the Commission to communicate with amateur stations. Amateur stations may be used also for transmitting signals, or communications or energy, to receiving apparatus for the measurement of emissions, temporary observation of transmission phenomena, radio control of remote objects, and for similar experimental purposes and for the purposes set forth in para. 97.91.

Part 97.91 **One-way communications.** In addition to the experimental one-way transmissions permitted by para. 97.89, the following kinds of one-way communications, addressed to amateur stations, are authorized and will not be construed as broadcasting:

(a) Emergency communications, including bona-fide emergency drill practice transmissions;

(b) Information bulletins consisting solely of subject matter having direct interest to the amateur radio service as such;

(c) Round-table discussions or net-type operations where more than two amateur stations are in communication, each station taking a turn at transmitting to other station(s) of the group; and

(d) Code practice transmissions intended for persons learning or improving proficiency in the International Morse Code.

Part 97.113 **Broadcasting prohibited.** Subject to the provisions of para. 97.91, an amateur station shall not be used to engage in any form of broadcasting, that is, the dissemination of radio communications intended to be received by th public directly or by the intermediary of relay stations, nor for the retransmission by automatic means of programs or signals emanating from any class of station other than amateur. The foregoing provision shall not be construed to prohibit amateur operators from giving their consent to the rebroadcast by broadcast stations of the transmissions of their amateur stations, provided, that the transmissions of the amateur stations shall not contain any direct or indirect reference to the rebroadcast.

Part 97.117 **Codes and ciphers prohibited.** The transmission by radio of messages in codes or ciphers in domestic and international communications to or between amateur stations is prohibited. All communications regardless of type of emission employed shall be in plain language except that generally recognized abbreviations established by regulation or custom and usage are permissible as are any other abbreviation or signals where the intent is not to obscure the meaning but only to facilitate communications

Part 97.69 **Radio teleprinter transmissions.** The following special conditions shall be observed during the transmission of radio teleprinter signals on authorized frequencies by amateur stations:

(a) A single channel five-unit (start-stop) teleprinter code shall be used which shall correspond to the International Telegraphic Alphabet No. 2 with respect to all letters and numericals (including the slant sign or fraction bar) but special signals may be employed for the remote control of receiving printers, or for other purposes, in "figures' positions not utilized for numerals. In general, this code shall conform as nearly as possible to the teleprinter code or codes in common commercial usage in the United States.

(b) The nominal transmitting speed of the radio teleprinter signal keying equipment shall be adjusted as nearly as possible to the standard speed of 60 words per minute and, in any event, within the range 55 to 65 words per minute.

(c) When frequency shift keying (type F1 emission) is utilized, the deviation in frequency from the mark signal to the space signal, or from the space signal to the mark signal shall be less than 900 cycles per second.

(d) When audio frequency-shift keying (type A2 or type F2 emission) is utilized, the highest fundamental modulating audio frequency shall not exceed 3000 cycles per second, and the difference between the modulating audio frequency for the mark signal and that for the space signal shall be less than 900 cycles per second.

Part 97.103 **Station log requirements.** Each licensee of an amateur station shall keep an accurate log of station operation, which shall include the following:

(b) The signature of each licensed operator who manipulates the key of a radiotelegraph transmitter; the signature of each licensed operator who operates a transmitter of any other type; and the name of any person not holding an amateur operator license who either directly or by recording transmits by voice over a radiotelephone transmitter or operates a teleprinter keying a radiotelegraph transmitter. (The signature of the operator need ony be entered once in the log, in those cases when all transmissions are made by or under the supervision of the signatory operator, provided a statement to that effect also is entered. The signature of any other operator who operated the station shall be entered in the proper space for that operator's transmission.)

Part 97.125. **Interference.** No licensed radio operator shall willfully or maliciously interfere with or cause interference to any radio communication or signal.

AMATEUR BANDS ON WHICH RADIO TELEPRINTER OPERATION IS AUTHORIZED AND TYPES OF EMISSION

Band	Emission Type	Identification
1800 to 2000 KHZ	No RTTY Authorized	
3500 to 3800 KHZ	Type F1	A1/F1
7000 to 7200 KHZ	Type F1	A1/F1
14000 to 14200 KHZ	Type F1	A1/F1
21.00 to 21.25 MHZ	Type F1	A1/F1
29.0 to 29.7 MHZ	Type F1/F2	A1, A3/F1, F2, F3
50.1 to 54.0 MHZ	A2/F1, F2	A1, A3/F1, F2, F3
144.0 to 147.9 MHZ	A2/F1, F2	A1, A3/F1, F2, F3

Other frequencies for A2, F1, F2 operation are:
220 to 225 MHZ excepting: In this band the amateur service shall not cause harmful interference to the government radio location service, and excepting: In those portions of the State of Texas and New Mexico in the area bounded on the south by parallel 31°53' N., on

the east by longitude 105°40' W., on the north by parallel 33°24' N., and on the west by longitude 106°40' W., the frequency band 220-225 MHZ is not available for use by amateur stations engaged in normal amateur operation between the hours of 0500 and 1800 local time Monday through Friday inclusive of each week. However, the entire frequency band 220-225 MHZ shall be available in all areas to those amateur stations authorized to operate in an organized civil defense network during all periods when civil defense emergencies exist and, in addition, special arrangements for civil defense drills between the hours and within the area set forth in this sub-paragraph may be made upon mutual agreement between the Federal Communications Commission Engineer in Charge at Dallas, Texas and the Area Frequency Coordinator at White Sands, New Mexico, if it appears necessary to conduct such drills. Such arrangements shall specify dates and times, and will depend upon the degree of use of the frequency band at White Sands at any particular time.

420 to 450 MHZ: In this band the amateur service shall not cause harmful interference to the government radio location service. Within the following areas, the DC plate power input to the final stage of the transmitter shall not exceed 50 watts, unless expressly authorized by the Commission after mutual agreement, on a case-by-case basis, between the Federal Communications Commission Engineer in Charge at the applicable District Office and the Military Area Frequency Coordinator at the applicable military base: (i) those portions of Texas and New Mexico bounded on the south by latitude 31°53' North, on the east by longitude 105°40' West, on the North by latitude 33°24' North, and on the west by longitude 106°40' West; (ii) The entire State of Florida, including the Key West area and the areas enclosed within a 200-mile radius of Patrick Air Force Base, Florida (latitude 28°21' North, longitude 80°43' West), and within a 200-mile radius of Eglin Air Force Base, Florida (latitude 30°30' North, longitude 86°30' West); (iii) The entire State of Arizona; (iv) Those portions of California and Nevada south of latitude 37°10' North, and the areas enclosed within a 200-mile radius of the U.S. Naval Missile Center, Point Mugu, California (latitude 34°09' North, longitude 119°11' West).

1215 to 1300 MHZ: Shall not cause harmful interference to the government radio location service

2300 to 2450 MHZ: Shall not cause harmful interference to the government radio location service. Operations in the frequency bands 2300 to 2450 MHZ are subject to such interference between 2400 and 2450 MHZ as may result from emissions of industrial, scientific and medical devices on the frequency 2450 MHZ. 3300 to 3500 MHZ: Shall not cause harmful interference to the government radio location service.

5650 to 5925 MHZ: Shall not cause harmful interference to the government radio location service. Operations in the frequency bands 5650 to 5925 MHZ are subject to such interference between 5775 and 5925 MHZ as may result from emissions of industrial, scientific and medical devices on the frequency 5800 MHZ. 10000 to 10500 MHZ: Shall not cause harmful interference to the government radio location service.

21000 to 22000 MHZ and above 40,000 MHZ there are no special restrictions.

Classification Of Emissions

For convenient reference the tabulation below is extracted from the classification of typical emissions in Part 2 of the Commission's Rules and Regulations and in the Radio Regulations, Geneva, 1959, and it includes only those general classifications which appear most applicable to the Amateur Radio Service.

Type of modulation	*Type of Transmission*	*Symbol*
Amplitude	With no modulation	AØ
	Telegraph without the use of modulating audio frequency (by on-off keying).	A1
	Telegraphy by the on-off keying of an amplitude modulating audio frequency or audio frequencies or by the on-off keying of the modulated emission (special case: an unkeyed emission amplitude modulated).	A2
	Telephony	A3[1]
	Facsimile	A4
	Television	A5
Frequency (or phase).	Telegraphy by frequency shift keying without the use of a modulating audio frequency.	F1
	Telegraphy by the on-off keying of a frequency modulating audio frequency or by the on-off keying of frequency modulated emission (special case: an unkeyed emission frequency modulated).	F2
	Telephony	F3
	Facsimile	F4
	Television	F5
Pulse		P

[1](In Part 97) unless specified otherwise, A3 includes single and double side band with full, reduced, or suppressed carrier.

Of all the above types of emission, the following are those specifically applicable to RTTY:

A2—Amplitude tone-modulated telegraphy.
F1—Carrier-shift telegraphy.
F2—Audio frequency-shift telegraphy.

General Practice Rules

Throughout this text it has been pointed out that 850 cycles was originally set as a standard f.s.k. shift. Since then as other shifts were used, there has been an attempt to make such

shifts multiples of 170 cycles. Any shift of less than 100 cycles used for c.w. identification purposes is frowned upon by the FCC. The FCC expects that the c.w. identification must be identifiable on a standard communications receiver.

It is generally accepted that, for an 850 cycle per second shift, the *higher* radio frequency signal represents the *mark* audio tone produced in the receiver which is 2125 c.p.s. (*lower* audio tone). Likewise, the *lower* radio frequency signal represents the *space* audio tone produced in the receiver which is 2975 c.p.s. (*higher* audio tone). The actual setting of the receiver b.f.o. to produce the above conditions depends upon the circuitry of the receiver. This was covered in detail under the "Two Tone Signal Reception" section.

In the a.f.s.k. system of RTTY the *low* radio frequency signal can, but not necessarily, represent the *mark* audio signal reproduced in the receiver. If this is not clear, one should review the section on a.f.s.k. in Chapter 3. Also, one should check the same section before assuming that it is OK with the FCC to tone modulate an s.s.b. transmitter to obtain an RTTY signal in the low frequency bands (80M, 40M, 20M and 15M). Refer, also to Chapter 2 and fig. 2.9 for the proper keyboard for use on the amateur bands.

It is also important to pay attention to Part 97.87, particularly that portion dealing with the 3 minute and 10 minute rules. The rules make it plain that an ID must be given for the RTTY station at least once for each and every 10 minutes of a QSO. The RTTY (printed) ID must include the call sign of station or call signs of stations you are in QSO with, as well as your own call sign. The c.w. or Morse Code ID need only include your own call sign. Names, initials or other superfluous letters transmitted between the "DE" and your own call is frowned upon by the FCC.

The F.C.C. expects regular amateur operations to respect emergency operations whether this be a radio net activity or an actual emergency. On the other hand, any group of radio amateurs that band themselves together in a so-called net cannot necessarily expect to monopolize a spot on the band simply because they call themselves a network. The actual activity of the group at any time should be the determining factor as to whether they have a right to expect all others to avoid their operating frequency. Good operating practice and common sense should apply.

Copying Other Speeds

From time to time, someone raises the question of the permissible use of Western Union machines with a code of 65 words per minute since Section 97.69 specifies a speed range of 55 to 65 w.p.m. The FCC has ruled that: "Since it appears that the use of the proposed equipment is normally not expected to impose any serious operating or monitoring problems, we approve the use of such equipment by amateurs."

As pointed out in Chapter 1, both the Bell system speed of 61.33 w.p.m. and the Western Union speed of 65 w.p.m. is based on a receiving shaft speed of 420 r.p.m., 368 o.p.m. and a code speed of 45.45 bauds. The difference in w.p.m. is due to the fact that the stop pulse of the Western Union code is 22 ms as compared to 31 ms for the Bell System machine code.

The Western Union speed is not to be confused with the European speed of 66.67 w.p.m. which is based on a receiving shaft speed of 461.5 r.p.m., 400 o.p.m., and a baud rate of 50. Recall the coverage of regenerative repeaters in Chapter 15 and their use as an aid in copying speeds other than the standard 60 w.p.m. (or 61.33 to be exact).

The TT-63AFGC Repeater is available and advertised from time to time. Try to obtain one of these if you intend working foreign RTTY DX.

Of course, there is another way. As pointed out earlier, a change in speed of the incoming signal will appear as an increase in distortion (bias). The operator may deliberately change the optimum setting (for normal or regular operating conditions) of the range finder of the teletype machine so that it samples the first or "front end" portion of the pulse instead of the customary middle of the pulse. The results obtained by this method may not always be too encouraging, depending upon transmission conditions, interference and freedom of the signal from distortion. A distorted signal to start with certainly compounds the problem.

As pointed out elsewhere in this text, the continual shifting of the range finder of a machine in a "last-ditch" effort to copy, is frowned upon. There are better ways to improve copy that are more rewarding.

Some RTTY'ers have solved the problem of copying speeds of foreign stations by obtaining a foreign make machine (covered elsewhere in this text) or else by using an extra American made machine that has been converted to the DX station's speed.

Radio Amateur Nets

The beginner usually gets a terminal unit going first and then starts casting around for signals to copy. Any QSO to monitor is OK.

One may find more activity on the nets, however, where interference is less and sustained copy material usually lasts longer.

There is MARS activity on 3347 kc and 6997.5 kc as well as a number of amateur nets that one may use for copying purposes or actual participation. One such radio amateur net is that of the Florida RTTY Society which meets each Sunday at 11:00 A.M. on 3700 kc. [45]Another Florida net is the Florida Amateur TT net (FATT) that meets every evening at 7:00 P.M. EST on 3700 kc. [46]Participation in this net by all RTTY'ers is encouraged.

W1AW transmits ARRL bulletins each evening by means of RTTY on 3,625 kc, 7,040 kc, 7,140 kc, and 14,095 kc. One should consult *QST* for exact times and any schedule changes from time to time.

Each year there is the Annual World-Wide RTTY Sweepstakes. Even if you do not get into the transmitting part of the contest you can have a lot of fun on the copying end.

45. Fred W. DeMotte, W4RWM, Sec. Treasurer.
46. Rex Peters, W4ZAG, Net Manager.

Another interesting amateur RTTY activity is the annual Armed Forces Day communications tests conducted each year in the late spring. This is a joint effort by the Departments of the Army, Navy and Air Force. These tests consist of cross-band operations from armed forces stations on spot frequencies outside the amateur bands to radio amateur stations in the appropriate sections of the amateur bands. In addition, there is a special RTTY receiving contest to test your ability to adjust and operate equipment with the goal of making perfect receiving copy on your teletypewriter equipment, including the receiver, terminal unit and teleprinter.

Press, Weather, And Other RTTY

Aside from the different speeds of DX stations, there are press, weather and various other teletype operations to be copied. Some of these use the Bell system of 60 w.p.m., 75 w.p.m., or 100 w.p.m., while others may use different speeds.

TABLE I Various Teleprinter 5-Level Codes[1].

Speed				Pulse Characteristics					Standard And/Or Use
W.P.M.	Operations or characters per min. (O.P.M.)	Receiver shaft speed (R.P.M.)	Keying Rate per sec. (BAUDS[2])	Start Pulse in MS.	Signal Pulse in MS.	Stop Pulse in MS.	Character Length in MS.	Character interval units[3]	
67.33	404	461.7	50	20	20	31	163	7.42	American Bell and American Amateur
65	390	420	45.45	22	22	22	154	7	American Western Union
66.67	400	461.5	50	20	20	30	150	7.5	Europe C.C.I.T. Standard
61.33	404	461.7	50	20	20	28.4	148.4	7.42	U.S. Miltary for operation with Allies
71.43	428.6	461.5	50	20	20	20	140	7	Europe - Former C.C.I.T. Standard
76.67	460	525.7	56.88	17.57	17.57	25	130.43	7.42	American-All commercial and military users
100	600	685	74.2	13.47	13.47	19.18	100	7.42	American-All commercial and military users
106	636	685	74.2	13.47	13.47	13.47	94.3	7	American military (limited use)

1. See Chapters 1 and 13 for details on teleprinter codes.
2. The baud speed is determined by dividing one second by signal pulse length. Thus in one second: $1/0.222 = 45.45$ bits (bauds) can be transmitted.
3. The code units are determined by dividing the character length by the signal pulse length. Thus $163/22 = 7.42$ units.

NOTE: Generally speaking — two or more codes are compatible when the receiver shafts of the respective teleprinters operate at the same speeds, and if the code speeds in bauds are also equal.

As pointed out earlier, many of the Bell System users of teletype service have gone on to faster speeds. Some of the various five level codes and their speeds and other characteristics are shown in Table I. Extensive details on the 5 level code were given in Chapter 1. Further details on the 5 level code were given in Chapter 13 along with details on the six and eight level codes.

Many of the press and weather stations make excellent sources of continuous copy for experimental purposes in connection with terminal units. The weather stations use so many abbreviations as well as special keys that it's pretty hard to get much from their broadcasts unless one has a weather keyboard and a complete key chart to the abbreviations. A good article on this subject appeared in the January, 1967 issue of the *Amateur Radio RTTY Journal*,[47] W8QMI gave the following schedule of WBR70 Miami, Florida weather station in G.M.T.:

2030 to 1400	3235 kc
Continuous	5937 kc
Continuous	8130 kc
Continuous	10,950 kc
Continuous	14,395 kc
1155 to 0500	16,440 kc

WSY, Sayville, Long Island, is another weather station. It is operated by the International Weather Bureau with offices in New York City. WSY operates continuously on the following frequencies: 5,940 kc, 8,110 kc, 13,620 kc, 16,250 kc, and 20,907 kc. Here again weather symbols and abbreviations are used which makes interpretation difficult even if perfect copy is obtained. Also, if your printer down-shifts automatically on space to letters this can complicate matters even more since the station does not necessarily transmit FIGURES after the transmission of SPACE if it is preceded by FIGURES. One would need to disable the automatic down-shift to letters feature of the teleprinter to avoid this problem. Other radio teleprinter stations recently operating at 60 words per minute are given in Table II.

TABLE II

Frequency in kc	Station Call
5247.5	WWA-65
6875.0	WWA-76
7682.5	WWA-87
7737.5	WFA-37
7745.0	WNA-67
11,115.0	WNC-21
14,741.7	WFD-54
15,537.5	WNC-64
16,207.5	WFD-66
17,700.0	WFL-71
23,355.0	WNE-33

Operating Notes

Some of the general good operating practices that apply for other modes of transmission apply equally well for RTTY communications. In addition, there are certain general practices that apply especially to RTTY communications. Even so, the operation of an RTTY station will vary, depending upon the station equipment, and the operator. The suggestions given in the following sections should take this into consideration.

Equipment Positioning

Some thought must be given to convenience, operating ease and comfort in the location of the RTTY equipment in the station. An operator with only a transceiver has no problem locating his equipment. As piece after piece is added to the shack the problem becomes more acute. One has to decide if the operating table is to be long or short or stacked (or both), in the form of a half-moon or U-shaped and if some or all of the equipment is to be rack or cabinet mounted. These are only some of the problems that one has to mull over and decide on as the station grows.

As equipment is added there comes a time when it may be a good idea to regroup and rearrange the station gear. A pretty good time to consider this is when adding RTTY to the station. The teleprinter needs to be at the normal height considered standard for any normal typewriter, 27 inches. The top of a 30-inch high table or desk is too high. The teletype machine or machines should be in easy reach without having to spin around or create the need for an operating chair with well oiled rollers. At the same time, the printers should not be between you and the receiver, the terminal unit and the various station controls.

Not to be overlooked is the proper disposal of used paper tape and page copy. Do not allow any great quantities of this to accumulate or float around the shack loose. As pointed out before, the use of a strip printer for continuous copy can put one knee deep in paper tape almost before you know it.

Provide for some place to store punched tapes of station layout details and other punch-recorded information that is used over and over. These tapes should be easily accessible while operating. A temporary place for these during QSO's and a more permanent place be-

47. Koch, E. W., "Interpreting the U.S. Weather Bureau Aviation Weather Transmissions," *Amateur Radio RTTY Journal*, Jan. 1967.

tween operating times would be the best answer.

How To Call

Keyboard calling procedure involves essentially the same good practice used for 'phone or c.w. In calling, the general practice of calling CQ or calling the other station three times and following the DE with your own call three times, repeating this procedure three times, is also recommended for RTTY. In addition, this should be followed with the usual K, then CAR RET, LINE FEED and LTRS in that order. These should be repeated unless band conditions are exceptionally good, particularly the CAR RET, and LTRS. This is not all, since there is the little detail of "dual identification" using Morse code and teleprinter code. The exact procedure of how this is accomplished follows.

In starting an RTTY transmission, the c.w. Morse identification should be sent first (FCC requirement) before switching to the teleprinter keyboard or punched tape sender (TD). It is assumed that the Morse code ID will be done with the carrier on, using narrow shift; otherwise, it will cause the receiving printer on the other end to print garble if it is turned on. This will move the printer down the line, away from the beginning of a fresh line. Then, when you finally get around to sending proper copy, the receiving machine is "out of step" and may start piling up characters at the end of the line long before you get around to sending CAR RET and LINE FEED.

With narrow-shift ID the printer normally rests on *mark* and prints nothing. You are now ready to switch to teletype. Before you do this, however, you should pause for a few seconds. Sometimes the operator on the other end may, for one reason or another, have the motor of his machine turned off. This will give him time to turn it on before you start your keyboard or tape sender.

Follow the Morse ID with LETTERS, pressing the LTRS key two or three times for good measure. It is also a good idea to press the carriage return and line feed keys. This doubly insures that the receiving machine is at the start of a new line and ready for your teleprinter signals. It is not a bad idea to press the line feed key two or three times. This puts some open space on the receiving page printer that separates your transmission (beginning of a QSO) from the receiving operators previous QSO, or whatever he previously printed. This makes it easier for him to quickly refer back to your various transmissions as the QSO progresses.

At this point do not forget to insert the teleprinter identification which is also required by the FCC. The procedure for this was given at the beginning of this section.

How To Sign

The sign is fairly simple. First you identify by teleprinter and then you identify by Morse code. If you have just called a station or if you already have a contact and this is the end of a subsequent transmission, the call of the station, as well as your own call, must be given in the teleprinter identification. Only *your own call* need be given in the Morse ID. This makes it possible to use some means of prerecording this Morse ID so that it can be sent automatically.

Unshift On Space

At numerous points in this text, the author has mentioned the automatic feature of many machines that unshift on space. This is done every time one presses the space bar and is considered a very desirable feature for amateur RTTY. Many times the amateur is operating under marginal conditions and fails to receive the LTRS character that is transmitted to return to letter characters. On the other hand, the sending operator may actually be sending letters (lower-case characters) and one of these is erroneously converted to the upper-case figures character by the time it is received. In either of the above circumstances the message is garbled from then on until the situation is corrected. Despite this, some operators block out the "unshift-on-space" feature of their machine. This is certainly a questionable practice.

Since there are machines in operation that have this feature and others that do not, it leaves an operator no choice but to keep this fact in mind at all times and act accordingly. For instance, if one is typing along, sending upper-case characters, the FIG key must be pressed each time that the space bar is pressed unless one is switching to lower-case characters at this point. If the latter is intended, one must also press the LTRS key anyway to take care of the fellows who have machines that do not automatically unshift on space.

While talking about the LTRS key it might be stated that it is a good idea to occasionally press this key for good measure when sending letters if the band conditions are marginal. The obvious purpose of this is to get the receiving machine or machines back on letter characters if a FIGS character has erroneously been received. This has no effect on the machines that are still on letters.

Despite the above facts, there are operators who still make a practice of changing from upper case to lower case by simply pressing the space bar. This would put a space in a call such as W5 VU for machines with unshift on

space and W5VU would be printed as W5;7 on the machines that do not unshift on space. Likewise, 73 turns out to be UE in many QSO's.

How To Talk—RTTY Style

Many amateurs, new to RTTY, tend to use c.w. practices in talking RTTY style. Calling and signing, as previously covered, can be similar, but the similarity should stop here. RTTY is a mode all its own and should be treated that way if one is to realize the full rich pleasure of RTTY work.

Abbreviations in c.w. work are understandable. A few of the old timers move along at fast clips, but the rank and file c.w. man does well if he moves much faster than twenty words per minute. This necessitates abbreviations. With tape transmissions or if one is a fast typist, RTTY can move along at three times this speed which lessens the necessity of abbreviating almost everything, as some newcomers to RTTY do.

Again, the use of the LTRS key is emphasized. There are a number of reasons why it is good practice for the sending operator to follow CAR RET and LINE FEED with LTRS every time a new line is to be started, even if letters were sent right up to the end of the line just ended. In the first place, the radio band conditions may be such that erratic conditions may shift the receiving machine to FIGS at any moment. If LTRS are sent at least once for every line, it adds some assurance that the receiving machine will keep trying to copy letters. In typing at 60 w.p.m., or with a TD feeding a tape, the characters are being sent pretty fast with little time between each. It does take time for the carriage return mechanism to function regardless of what type and model it may be. Throwing in the LTRS function just gives the carriage return mechism on the receiving machine that much more time to function. Otherwise the *first* character may print somewhere along the way from right to left on the page and probably between the old line and the new.

Many modern teleprinters have automatic carriage return and automatic line feed features. Such kits can be obtained for older machines such as the Teletype Models 15 and 26. Quite a number of the RTTY'ers have this feature on their machines. Even so, so long as there are a goodly number that do not have this feature, one must continue to send these two functions. Most of the machines that have this feature have them set pretty near the end of the line. By pressing the carriage return and line feed keys before these automatic features take effect (on receiving machines that have them) can save paper for the operators with such machines.

This may seem to defeat the purpose of such a device and it does partially do so, so long as all do not have such a device. On the other hand, you never have to worry about missing the carriage return and line feed signals, if your machine has this automatic feature. If they are sent and you miss them or if the sending operator forgets to send them, the automatic feature of your machine functions.

Tape And Manual Sending

One's typing speed can be a factor in the degree of correct copy on the other end. A slow typist, hunting and pecking a key here and there can get lost in the garble with marginal band conditions. The uniform and smooth sending speed of tape transmitting machines cannot be duplicated, even by an excellent typist. For this reason, it is considered that better receiving copy results from tape sending than from manual sending when band conditions are marginal.

There is no doubt that a tape sender can add much to the flexibility and pleasure of an RTTY station operation. One must have the switching and programming circuitry that makes the tape machine operate automatically or semi-automatically, in order to take advantage of their full potential. They must be easily accessible for such tape changes as are necessary. One tape machine with just a "CQ loop" and a station description tape can add much to RTTY operating pleasure.

Correcting Errors

Once an error is made in typing on a teleprinter keyboard it is already printed on the other end of the QSO. About the only sensible thing to do is to send a series of E's ofx's and start over at the appropriate point.

An error on a punched tape can be corrected if the reperforating mechanism can be backspaced. It will be noted from fig. 1.2, Chapter 1, that the LETTERS character is formed by a mark signal for all five of the intelligence elements of the code. The LETTERS character has no symbol that is printed. Therefore, if one can back-space a tape, the error character can be repunched with the LETTERS key which punches the remaining space bits or elements or levels of the code. After this is done, one can follow by reperforating the correct character.

Zero Beat

One should zero beat his own transmitter carrier (*mark*) frequency with the carrier

(*mark*) frequency of the station about to be called. This should be done regardless of the shift used or if they should happen to be different.

This is also the way to start the process of breaking into a roundtable QSO. There are variations of how this can best be done from this point on. Few operators give very much attention to the Morse ID that the sending operator ends with, except to note when it is finished and the carrier is turned off. It is during this ID period that it is most practical to "break" the QSO. This should be done as soon as possible. First there may be the problem that the receiving operators machine is no longer on LETTERS, depending upon how the Morse ID (in progress) has affected his machine. For this reason, it is a good idea to press the LETTERS key rapidly several times and then print BK several times, followed by your call and, lastly, give your Morse ID and stand by.

Government Technical Manuals

TM11-235	Radio Sets SCR-536-A, -B, -D, -E, and -F
TM11-257	Frequency Shift Exciters O-39/TRA-7, O-39/TRA-7
TM11-261	Dual Diversity Converters CV-31/TRA-7
TM11-262	Control Units C-202/TRA-7
TM11-264A	Radio Set AN/GRC-26A. (Included in this manual are descriptions and schematics on the following equipment. BC-610-H & I Xmtrs, RA-87 Rectifier, BC-610 tuning units, R-388 (51J3) Receiver, O-39 Freq. Shift Exciter, CV-182 Freq. Shift Converter, BC-614 Speech Amp., PP-712 Power Supply and Tone Osc., Antenna Tuning Unit BC-939, Multimeter TS-352 Wiring diagram and PE-95 data
TM11-278	Radio Teletype Equipment AN/TRA-7
TM11-352	Printers TG-7-A, B, TG-37-B, Chests CH-50 and CH-62
TM11-353	Installation and Maintenance of Telegraph Printer Equipment
TM11-354	Telegraph Printer Sets (Teletypewriter) EE-97 and EE-98 Teletypewriter Sets EE-97-A, EE-98-A, and EE-102
TM11-355	Telegraph Terminal CF-2-A (Carrier).
TM11-355B	Telegraph Terminal CF-2-B (Carrier).
TM11-356	Radio Terminal Equipment AN/FGG-1
TM11-358	Telegraph Central Office and Switchboard BD-100 (being revised)
TM11-359	Line Units BE-77, for use with TG-7
TM11-410	The Homing Pigeon
TM11-464	The Teletypewriter Operator
TM11-486	Electrical Communication Systems Engineering
TM11-487	Electrical Communication Systems Equipment
TM11-624	Radio Set AN/MRC-2
TM11-655	Fundamentals of Telegraphy (teletypewriter)
TM11-680	Teletypewriter Circuits & Equipment (fundamentals
TM11-834	Radio Telegraph Transmitter, Press Wireless PW-981-A
TM11-872	Diversity Receiving Set AN FRR-3, Press Wireless
TM11-957	Rectifier RA-87 (teletype power supply)
TM11-889	Diversity Receiving Equipment (RCA Model DR-89) (includes schematic on RCA Model AR-88F Receiver)
TM11-1177	Pulse Generator Set AN UPM-15
TM11-2001	Complete 100-mile Spiral-Four Carrier System
TM11-2004	Repeater Set TC-18 (Terminal, Telegraph)
TM11-2005	Repeater Set TC-19 (Intermediate)
TM11-2009	Telegraph Terminal CF-6 (Carrier)
TM11-2022	Application of Packaged Equipment to Open-Wire Lines
TM11-2028	Telephone Repeaters OA-7 FC and OA-8/FC (Voice frequency telephone repeater: Packaged equipment.
TM11-2032	DC Regenerative Telegraph Repeater
TM11-2200	Bias Meter I-97-A
TM11-2201	Reperforator Teletype Sets TC-16, TC-17; (TG-26, TG-27)
TM11-2203	Teletypewriter Set AN/TGC-1
TM11-2204	Teletype Sets AN/TGC-1 (torn tape console)

TM11-2204	Dual Diversity Receiving Equipment, Wilcox CW-3-D
TM11-2205	Exciter Units O-5/FR, RF Oscillator O-80/FRT
TM11-2206	Telegraph Terminal Set AN/TCC-1, Telegraph Terminal TH-1/TCC-1 and Filter F-2GG.
TM11-2207	Radio Teletype Code Room and Signal Center, Installation Procedure and Maintenance Guide
TM11-2210	Teletype Set TT-10/FG, 132A-2 Teletypewriter Subscriber Set, with Model 14 Equipment
TM11-2211	133A-1 Teletypewriter Table, with Model 14
TM11-2214	133A-2 Teletypewriter Subscriber Set, with Model 14 Equipment
TM11-2215	Teletypewriters TT-5/FG and TT-6/FG
TM11-2216	Teletypers TT-7/FG and TT-8/FG
TM11-2217	Distortion Test Set TS-383 GC
TM11-2222	Receiving - Transmitter Distributors TT-12/FGQ, TT-13/FGQ; Transmitter Distributors TT-21, TT-25, TT-26, TT-52/FG, including other Model 14 Transmitter Distributors
TM11-2223	Typing and Non-Typing Reperforators, Model 14
TM11-2224	Teletypewriter Test Set TS-G11/FG
TM11-2225	Teletypewriter Set AN/GGC-3, Reperforator Transmitter TT-76/GGC
TM11-2226	Teletypewriter Reperforator TT-107/FG
TM11-2228	Test Set TS-2/TG Teletype Distortion, Signal
TM11-2230	Teletypewriter Sets ANF/GC-20, AN/FGC-20X and AN/FGC-21 (Manaul contains instructions for the installation, operation, theory, maintenance and repair of the above sets)
TM11-2234	Teletype Set AN/TT-4/FG
TM11-2236	Teletype Set AN/TT-61-FG
TM11-2239	Telegraph - Telephone Terminal AN/TCC-14
TM11-2241	Frequency Shift Converter CV-116/URR
TM11-2242	Telegraph - Terminal AN/TCC-4 and AN/TCC-20
TM11-2249-25	Teletypewriter Sets AN/TGC-5 and AN/TGC-5X
TM11-2271	Teletypewriter Page Printing Mechanisms, (Kleinschmidt)
TM11-2272	Teletype Page Printing Mechanism, (Kleinschmidt)
TM11-2513	Test Sets I-193-A, I-193-B, and I-193-C
TM11-5062	Frequency Shift Converter CV-182/GRC-26A, PP-172/GRC-26
TM11-5524	Frequency Shift Converter CV/62U 3A and Reperforator - Transmitters, Teletypewriter TT-76/GGC, TT-76A/GGC, and TT-76B/GGC
TM11-5815-200-10	Teletypewriter Sets AN/FGC - 20, FGC - 20X, FGC-21 and AN/UGC-4 Operators Manual
TM11-5815-200-35	Teletypewriter Sets AN/FGC - 20, FGC - 20X, FGC-21 and AN/UGC-4 Field and Depot Maintenance
TM11-5815-244-12	Teletypewriter Sets AN/FGC - 25, FGC - 25X, FGC-26 and AN/FGC-57 Operation and Organizational Maintenance
91490 Navyships	Frequency Shift Converter Comparator Group AN/URA-8A, CV-89 URA-8A
Technical Manual	Teletypewriters TT-47C/UG, TT-48B/UG, TT-69B/UG, TT-70C/UG, TT-128A/UG, TT-129A/UG, TT-130A/UG, TT-131A/UG, TT-171/UG and TT - 234 / SGA - 3. Navyships 93241 (Teletype Corp.)
Instruction Book	132W1 Teletypewriter Station Equipment. (WE) (Includes wiring diagrams for 14Y typing reperforator unit, 14N Teletypewriter base, type 14 Transmitter - Distributor, 14AB AC governed motor 14AA synchronous motor, 14H & 14 L Transmitter - Distributor, 14H synchronous motor, and some others also.)

Handbook Operating Istructions	Telegraph Repeater Unit
Technical Manual	Teletypewriter Mixer SSM 33 Typing Reperforator Model 14 (Teletype Corp.)

Abbreviations

ac	Alternating Current
CAR RET	Carriage return
CH	Channel
contd	continued
cu ft	cubic foot (feet)
db	decibel (s)
dc	direct current
diam	diameter
F	Fahrenheit
fig.	figure
FIGS	figures (position)
ft	foot (feet)
ga	gauge
in.	inch(es)
lb	pound(s)
LTRS	letters
ma	milliampere
mf	microfarad
opm	operations per minute
rpm	revolutions per minute
w	watt
wpm	words per minute

Glossary Of Terms Used In Teletypewriter Maintenance

Adapter. An accessory used to change or alter an electrical plug, or the like, so as to render it suitable for a new mounting.

Bias. Line bias: the effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called *marking* bias; if the received signal is shorter, it is called *spacing* bias.

Bias, applied. A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Bias distortion. The distortion produced by bias.

Bias meter. A meter for measuring the amount of marking or spacing bias that may be present in a transmitted signal.

Break contact. That contact of a switching device which opens a circuit upon the operation of the device.

Break key. On a teletypewriter, the key used to break into the transmission being received from another station.

Capacitance. The ability or capacity to receive an electrical charge.

Capacitor. A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Carrier current. A current upon which is impressed a current of another frequency to transmit intelligence.

Carrier frequency. The frequency of the carrier current.

Centrifugal. Proceeding or flying away from the center.

Centrifugal force. A force which impels a body, or parts of a body, outward from the center of rotation.

Characteristic. A distinguishing trait, quality, or property.

Closed-circuit system. A telegraph system in which, when no station is transmitting, the circuit is closed and current is flowing in the circuit.

Cycle. In a periodic phenomena, one complete set of recurring events.

Decibel. A unit of transmission expressing a relation between input and output power.

Differential. Pertaining to, or involving, a difference; that is, a differential current device is one which operates upon the basis of a difference in two current values.

Distortion. An alteration or a deformity of a waveform.

Duplex. Operation in two directions simultaneously over one circuit.

Filter. A device for preventing the passage of current of certain frequencies while allowing currents of other frequencies to pass.

Frequency. In periodic phenomena the number of vibrations or cycles in unit time; in alternating current the number of cycles per second.

Function. The duty or job performed by a device. With regard to teletypewriters, the mechanical operation of line feed, carriage return, space, letters shift, figures shift, unshift on space, and motor stop.

Fuse. A wire, bar, or strip of fusible metal inserted as a safety device in an electric circuit. When the current increases beyond the rated strength of the fuse, the metal melts and thus interrupts the circuit.

Fusetron. A fuse equipped with an overload feature. A fusetron will take a starting load up to 50 percent in excess of its rated value for a short period of time before blowing. Has a base connection similar to a fuse.

Fustat. A fuse equipped with an overload feature the same as a fusetron, but having a different base connection. Must be used with an adapter for insertion into a fuse socket.

Gear. A set of appliances as of cog wheels, serving to transmit motion or change its rate or direction.

Governor. An automatic attachment to a motor for controlling the speed of rotation.

Ground. The contact of a conductor with the earth; also the earth when employed as a return conductor.

Grouping circuits. Circuits used to connect two or more switchboard positions together so that one operator may handle the operation of those positions from his own operator's set.

Insulator. A nonconducting substance or body.

Jack. In combination with a plug, a device by which connections can readily be made in electrical circuits.

Key. A hand-operated device for the rapid opening and closing of a circuit or circuits.

Keyboard perforator. A mechanism consisting of a keyboard and a perforator by which means a tape is perforated in accordance with a code corresponding to the depressed character key of the keyboard.

Latch. To secure or fasten as with a catch.

Leakage. Current loss through imperfect insulation.

Lever. A mechanical device; a beam pivoted on a fixed point or fulcrum, serving to impart pressure or motion to exert effective power.

Lockwasher. An open, spiral, spring tempered steel washer for preventing the loosening of nuts.

Loop. Subscriber's loop: The pair of conductors connecting a subscriber's instruments with the main frame of the central office. Loop mile: the resistance of a pair of conductors between two points one mile distant; the resistance of the two conductors connected in series.

Make contact. That contact of a device which closes a circuit upon the operation of the device.

Marking contact. That contact of a telegraph relay which is closed when marking current is controlling the relay operation.

Marking current. That magnitude and polarity of current in the line when the receiving mechanism is in the operated position.

Microfarad. Practical unit of capacitance; one-millionth of a farad.

Milliampere. Unit of electric current; equal to one-thousandth of an ampere. Usually referred to as ma.

Ohmmeter. A direct reading instrument for measuring resistance, calibrated in ohms.

Opm. Operations per minute.

Patching. Temporarily connecting together two lines or circuits by means other than switchboard cord circuits.

Patching cord. A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Period. The time required for the completion of one cycle.

Platen. The part of a typewriter or teletypewriter on which the paper is supported to receive the impression.

Plug. In combination with a jack, a device by which connections can readily be made in electrical circuits.

Polar. A system of telegraphy in which the current in the line is reversed in polarity in changing from marking to spacing.

Polarential. A telegraph transmission system in which transmission in one direction is polar with equal and opposite transmitting voltages for marking and spacing, and transmission in the other direction is differential with voltage applied for the spacing condition and ground for the marking condition.

Polarized plug. A plug that is so constructed that it can be inserted into an outlet in only one way.

Pulsating current. Current of varying magnitude but constant direction.

Range. The upper and lower limits through which the index arm of the range-finder mechanism of a teletypewriter may be moved and still receive correct copy.

Rectifier. A device for changing alternating current to pulsating direct current.

Repeater. A device for the retransmission of a signal, usually with amplification.

Repeating coil. An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Reperforator. A device for receiving teletypewriter signals as electrical impulses from a line and converting them into perforations in a tape.

Retardation coil. A coil offering high impedance to voice-frequency currents but low impedance to direct current.

Rheostat. A variable resistance for limiting the current in a circuit.

Simplex. A method of obtaining an additional telegraph channel by the use of repeating coils.

Spacing contact. That contact of a telegraph relay which is closed when a spacing impulse is controlling the relay operation.

Spacing impulse. That period of time in which the circuit polarity of current is reversed or, in a neutral system, when the signal line is opened, the receiving mechanism is caused to be in the unoperated or released position.

Switch. A device for opening, closing, or rerouting an electrical circuit.

Switchboard. A board containing apparatus for controlling or connecting electrical circuits.

Synchronism. The state of being synchronous.

Synchronous. Having the same period and

phase; happening at the same time.

Teletypewriter. An electromechanical device for the transmission of characters as electrical impulses, and the reception and printing of characters to correspond with the impulses received.

Teletypewriter code. A special code in which each code group is made up of five units or elements of equal length. These units or elements are known as marking or spacing impulses.

Terminal. One end of an electrical circuit.

Transmitter distributor. A distributor consisting of a rotating arm with brushes in contact with conducting segments of a circle; used in the transmission of teletypewriter signals.

Trunks. A circuit between two switchboards, central offices, switchboard positions, or other parts of a wire plant, but not to any subscriber.

TWX. A trunk between teletypewriter central offices. In the Army, TWX usually refers to trunks from Army teletypewriter switchboards to commercial switchboards; or a message that has been transmitted through a commercial teletypewriter exchange.

Voice frequencies. Those frequencies covered by the range of human voice (usually below 3,000 cycles per second).

Zero bias. When the received signal is equal to the transmitted signal (neither longer nor shorter), the circuit is said to have zero bias.

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